## The Book of Trees

Do you love trees? Do you want your children to love trees? Do you wish to leave for posterity something grander and more magnificent than the pyramids, palaces or cathedrals left behind by kings, emperors and sultans?

In *The Book of Trees*, Risto Isomäki (Finland) and Maneka Gandhi (India) provide every human being on the planet with that dazzling opportunity: raising majestic forests that will survive for thousands of years. They recount for us fantastic stories about trees collected from across the planet. They discuss the significance of trees for alleviating hunger and cooling the earth. They document the most important tree species of our planet and include a practical chapter on the raising and breeding of trees.

*The Book of Trees* is a grand celebration of the companionship of trees.

*Risto Isomäki* is a writer, a former chairman of Friends of the Earth Finland and secretary of the Coalition for Environment and Development (CED).

*Maneka Gandhi* has been Minister of Culture, Minister of Environment and Minister for Empowerment and Social Justice in the Government of India. She also heads People for Animals, India's largest animal welfare organisation.

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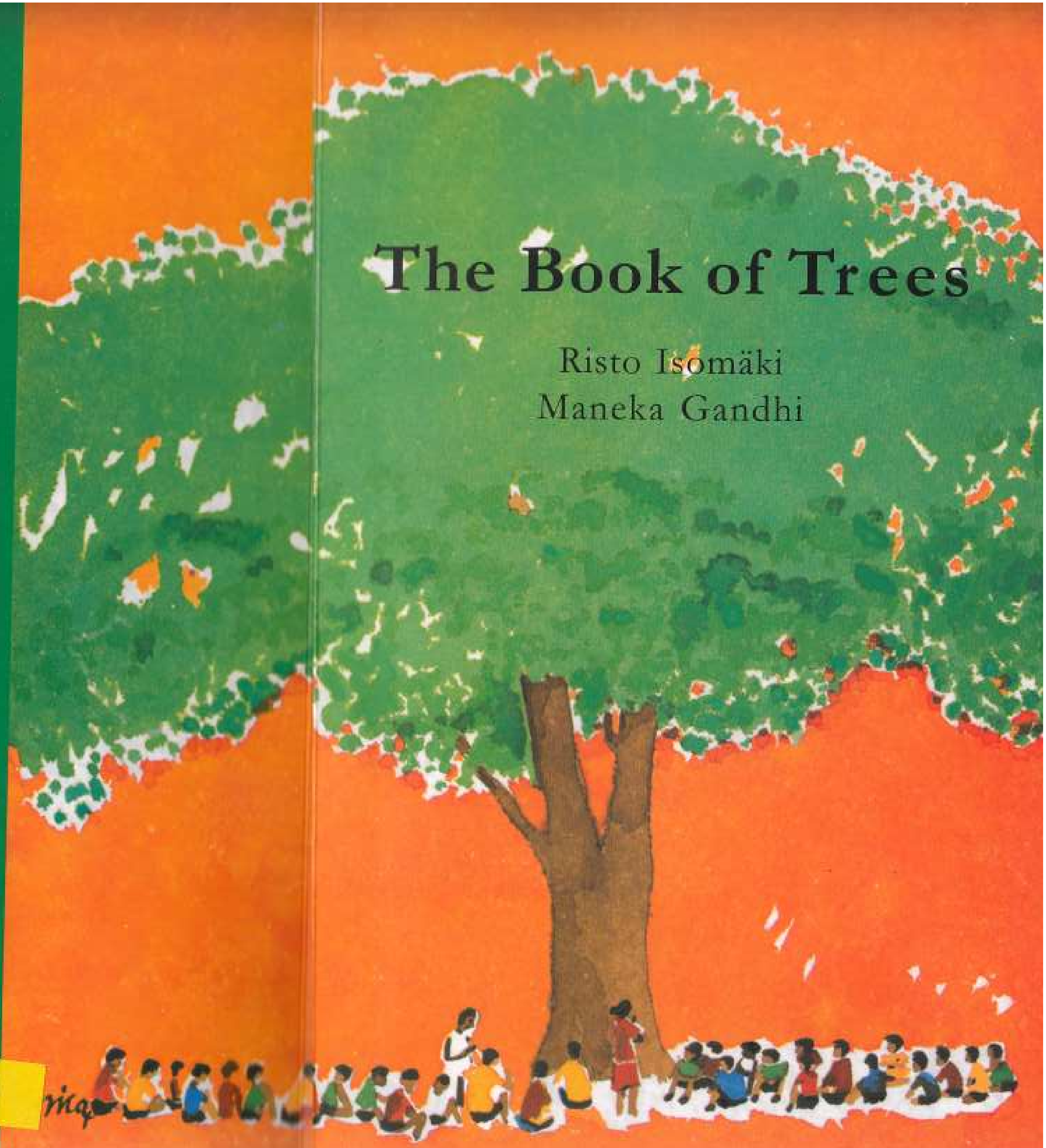

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*A Vasudhaiva Kudumbakam perspective*

Risto Isomäki
Maneka Gandhi

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*by* Risto Isomäki and Maneka Gandhi

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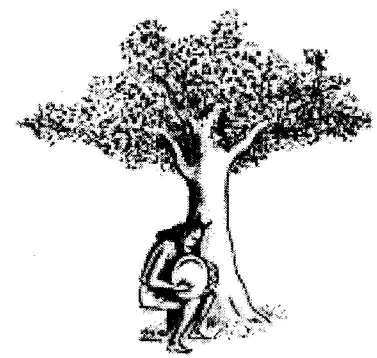


*The ripe, golden grain fields had once been the symbols of well-being. But already in the period of a united world the unprofitability of annual farming has been acknowledged. The demanding toil of cultivating annual plants and bushes was stopped... There were thousands of different varieties of breadfruit, berry and nut bushes, each bush producing hundreds of kilograms of protein-rich fruit. These forests extended round the world for hundreds of millions of hectares in two wide belts. They were the real Belts of Ceres, named after the mythical ancient God of Fertility.*

—The Utopia of Ivan Jefremov, a soviet science fiction writer, about the world in the fourth millennium, in *The Galaxy of Andromeda*, 1958

# Contents

# Introduction

IN HIS OLD AGE, Gandhiji decided to start eating food that was only produced by trees. Besides this, he also drank some goat's milk. Even many of his closest followers did not understand the point, and considered the decision an old man's folly. However, Gandhiji, as usual, saw much further than other people in this matter too. His decision demonstrated a very important point, which is also the main focus of this book.

Another giant of human history, the Buddha, also emphasized the importance of food produced by trees. Buddha instructed his followers to plant five trees every year and to ensure that they remained alive. Each one of us can make a very important contribution towards solving the problems of hunger and environmental degradation by planting various food-producing trees, especially trees that can attain a larger size, and by letting them grow to an old age.

Trees can produce, for the same area of land, more food than other kinds of food-producing plants, especially if various trees of different sizes are grown together. Trees can produce food in rocky and marginal soils, mountain slopes and dry lands, where ordinary field farming is impossible. And most tree species will keep on producing food even during drought or flood or during periods of war when the cultivation of annual crops is interrupted by mindless fighting. By planting and growing food-producing trees we could, perhaps, make hunger and malnutrition things of the past.

In human history, the ordering of the construction of large palaces and cathedrals or pyramids that have sometimes been preserved for hundreds, or even thousands, of years, has been the privilege of a very small and select group of emperors, sultans and kings. However, if we want to do so, every one of us can, on a personal or community basis,

plant things that are much larger, tremendously more beautiful and much more useful than all the cathedrals and palaces in the world put together.

We can plant small forests of sequoia trees, that can achieve heights of 100 or 120 metres and diameters of 10 metres, and that can live for 6,000 years. Or we can plant majestic baobab trees that can keep on producing nutritious fruits, nuts and leaves for human consumption even when they are 4,000 or 5,000 years of age.

Or we can plant aspens, organisms that are almost eternal, whose vast root systems can sometimes live for more than a million years. If we manage to establish a growth of useful mycorrhiza fungi-producing edible mushrooms into the root systems of the aspen trees before we plant them, we might be able to establish aspen forests that will still be producing food for humans after a million years. In this way, a small act carried out in our own lifetime would benefit people and animals that will inherit the earth after us, for 50,000 coming generations, or more.

Or we can contribute to the preservation and protection of the already existing larger trees, and ensure that they will have the chance to reach an old age typical to their own species, and that they will be given the chance to die as slowly as they have lived - in their natural way. In this way, we can make the world a much more wonderful and beautiful place, a place where every square kilometre would, after a few thousand years, be full of great wonders and the splendour provided by the trunks, branches and leaves of gigantic trees.

*December, 2003*
*New Delhi, India Helsinki, Finland*

# 1

# Trees as Food Producers

According to John Sholto Douglas and A.J. de Hart, only about 8–10 per cent of the world's land area is currently being cultivated, but this area already includes a very large majority of all existing good-quality farmlands. Tree crops, however, could theoretically be grown on at least 75 per cent of the world's land area. Trees can also be grown on lands that are not suitable for conventional field farming, including arid and semi-arid lands, steep hill slopes and rainforest lands.

This fact might turn out to be very important during the next century, because there are already about twelve hundred million people suffering from hunger in the world—and the pressures on our present food production system are increasing with a frightening speed.

We might have, in 2100, 10 or 12 billion people living on earth—up to twice the present number. Even much more than the growth of the human population in itself, the so-called consumption explosion is increasing the pressures on our agricultural production systems at an alarming rate. The production of biomass fuels for cars and lorries, the production of wood for paper mills, the production

of fodder for European and North American cows and pigs, as well as other new consumption needs of the global upper and middle classes, are competing for the same, limited, shrinking resource base. This could be even more serious than population growth.

The American Worldwatch Institute has estimated that, if the world's food production is raised by 15 per cent, the world could provide a typical Indian diet for 10 billion people, an Italian diet for five billion people but an American diet only for 2.5 billion people. Indian diet, in this context, means an amount of mostly vegetarian food that is sufficient to cater to the nutritive needs of a person. Italian diet refers to a diet that, on average, contains somewhat more meat than Indian food, and the American diet refers to the consumption patterns typical for the United States of America, where most of the grain, milk and fish production is fed to cattle in order to produce meat for human consumption.

Perhaps the most serious issue, in this context, is the way the middle and upper classes in Asia are rapidly abandoning traditional vegetarian values, and starting to imitate western eating habits—which means that they are rapidly increasing their consumption of meat. However, the more people abandon their vegetarian values, the less food will be left for the poorer segments of the population—and for the animals.

At the same time, humanity is in danger of losing a major part of its most productive farmlands. According to the Worldwatch Institute, about 65 per cent of all agricultural land in Africa, 45 per cent in South America and 38 per cent in Asia has already been degraded, at least to some extent.

According to the UN Food and Agriculture Organization, erosion might reduce the overall productivity of the world's rainfed farmlands by 30 per cent within a few decades. Even larger areas are suffering from declining fertility. Phosphorus deficiency affects 73 per cent of farmland in China and 80 per cent in Pakistan. Between one-third and one-half of the world's 230 million hectares of irrigated farmland is suffering from salinization or waterlogging.

In most of India, Pakistan and Bangladesh, in practically every important agricultural area of China, and in much of the USA, Middle East and North Africa, groundwater reserves are being depleted because of the overuse of water for irrigation purposes and because of the loss of tree and vegetative cover, which has reduced the recharge of the water resources. According to the International Irrigation Management Institute, India is already consuming its groundwater resources twice as quickly as they are being replenished, and the level of groundwater is declining by 1–3 metres a year in many parts of the country.



Population Action International has predicted that between 2,800 and 3,500 million people could be suffering from acute water shortages by the year 2025. According to the GEO 2000 programme of the United Nations, up to two-thirds of humanity might soon suffer from a lack of water.

The situation is likely to get worse because of global warming. It has been estimated that if the global temperature rises by four degrees Celsius, the tropics will receive 12 per cent more rainfall—but the evaporation rate will increase by 30 per cent. This means that the tropical and subtropical regions would, in practice, become much drier.

The Intergovernmental Panel on Climate Change (IPCC) has estimated that the flow of the Nile could be reduced by 75 per cent because of global warming, and that the Indus might suffer almost as dramatically. If the climate becomes hotter and the evaporation rate increases, more irrigation water will be needed to produce the same results. The growth of the human population also increases the pressures on the decreasing water resources. This means that many countries need to look for alternative strategies for producing enough food for their citizens. At the moment, 70 per cent of China's and 50 per cent of India's grain comes from irrigated fields, but the present food production system may not be on a sustainable basis.

More and more good-quality farmland is being lost due to urbanization and automobilization. For example, in the United States each additional automobile has meant the loss of 0.06 hectares of cultivable land. Smaller areas of cultivable lands are also lost due to various pollution problems, or due to big dams, mines, factories and other development projects, which—according to a recent World Bank report—have annually displaced eight or nine million people during the last decade. If global warming leads to a rise in sea levels,

we may also lose a major part of the fertile farming lands in the coastal areas.

When all these factors are counted together, it becomes very clear that the pressures on the world's remaining uncultivated lands will increase tremendously during the twenty first century.

The main problem here is that the remaining uncultivated lands have remained uncultivated because they are marginal lands—mountains, (rain)forests and drylands—that are difficult to cultivate and especially vulnerable to erosion. If they are cultivated in the wrong way, their inherent meagre fertility can be rapidly depleted, and after that, the peasants will have to move on to find new areas to be cleared for cultivation—if they can still find any.

The growing of various food-producing trees—together with other kinds of plants—is likely to become one of the most important, or perhaps even the most important, answer to these problems.

Trees can be grown on all kinds of marginal lands where conventional agriculture would be impossible, or next to impossible—on poor and rocky soils, in arid and semi-arid regions, rainforest lands and steep hill slopes. Moreover, multi-storey farming systems, mixing tree crops with other kinds of plants, can, in practically every conceivable ecosystem, produce more food per hectare—in terms of calories, proteins and other nutrients—than conventional farming.

The tree components alone can, in most cases, produce much more food than conventional farming systems. The explanation for this fact is simple: trees are much taller and they have much deeper roots than annual plants. For these reasons, trees can collect a larger amount of sunlight and carbon dioxide from the air, and also utilize—besides surface water—moisture and nutrients from the deeper soil layers.

The emergence of tree planting as a widespread custom seems to be a more or less spontaneous and automatic process that is takes place when the population densities reach certain levels and continue to grow beyond them. This can already be seen in many regions of the world. Wherever population densities have reached a



## How the Coconut Came to Earth

Trishanku was a famous king of the Solar dynasty. He was a pious ruler, renowned for his devotion to the gods. Trishanku had only one desire. He did not want to wait till he died and his soul went to heaven. He wanted to go there with his mortal body intact.

There was a great famine in the country. Sage Vishvamitra and his family lived in a forest of the kingdom. The sage had gone away to another country and his family was starving. Trishanku helped them with food.

When Vishvamitra returned to his hermitage and heard of Trishanku's deed, he promised to help the king achieve his desire. He started a *yagna* or sacrifice to the gods. As the fire and the prayers grew in strength, Trishanku started rising off the ground. Soon he was far above the earth, above the clouds, and had neared the gates of *svargaloka* where the gods lived.

As soon as the gods saw a mortal at the gates, they ran complaining to their king, Indra. Indra, angry at the daring of Trishanku, pushed the king down again.

As Trishanku fell, he cried out in fear to Vishvamitra. The sage looked up and saw the unfortunate king falling fast through the sky. His anger knew no bounds. He shouted: 'Let Trishanku stay where he is.'

Trishanku stopped in mid-air. But the sage knew that the king would only be able to stay aloft for a little while and soon the magic chant would wear off. So he held him up with a long pole.

In time, this pole became the trunk of the coconut tree and Trishanku's head became the coconut fruit.

certain level, they have also led to the development of multi-storey, multi-species agroforestry systems known as tropical home gardens.

In southeastern Nigeria, where population densities range as high as one thousand people per square kilometre, the high population densities are usually linked with more trees.

Similar trends can be observed, for example, on the densely populated slopes of Kilimanjaro and Meru in Tanzania and Kenya, on the island of Zanzibar, in Rwanda, China, India and Java—where tropical home gardens cover 75 per cent of all agricultural land.

In Kenya, both the government and dozens of non-governmental organizations have actively encouraged people to plant their own trees. This has made Kenya the first country in Africa that has reversed the decline of living biomass. According to the latest studies, the biomass—the combined amount of trees and other vegetation—is now growing in 39 out of the 42 districts, of Kenya. And in many districts the growth has been rather spectacular.

The reason for these trends is obvious: home gardens involving various tree crops are more productive. For example, in the heavily populated areas of Nigeria, the production of the multi-storey gardens is, in monetary terms, five to 10 times higher than that of conventional field farming.

It has been estimated that fruit trees only occupy 2–3 per cent of the world's agricultural land, but contribute 5–7 per cent of the gross food production and 10–35 per cent of national income from agricultural production. It must be pointed out here that, at the moment, much of the commercial fruit production concentrates on fruits that have a relatively low nutritive value but that are commercially valuable, like the citrus fruits.

As the population densities of many Third World countries are projected to multiply before the end of this century, it could be expected that the various agroforestry and tropical home garden systems involving tree crops are likely to become the dominant mode of small-scale agricultural production in many, if not most, Third World countries.



## Dry Areas: The Hunger Zone

In areas that have very uncertain rainfall, the security of food production is the number one consideration of the poorer segments of the population. In such areas, tree crops are especially important, because trees are likely to provide a crop even during bad drought years, when all the (rainfed) annual crops will fail.

The world has altogether 6.1 billion hectares of drylands, if hyper-arid, arid and semi-arid lands are all included. Already about one billion people live on drylands, which will most probably have to feed a growing percentage of the world's population in the future. Because the trees and other plants growing in arid places have never received the attention of plant breeders, people moving to drylands usually attempt to cultivate familiar plants which require large, or relatively large, amounts of water to survive and produce crops. This results in very insecure food crops: in drought years there may be no crop at all. For this reason, already 90 per cent of all international food aid is going to drylands.

The domestication of various wild fruit and nut trees growing on drylands might be the single most important answer to these problems. Tree crops are likely to constitute one of the, (or the), agricultural technologies best suited to very arid conditions.

Food-producing trees can be grown also on lands that cannot be used for conventional field farming. Moreover, food-producing trees can probably produce much more protein, fat and carbohydrates per hectare than any other food crops that can be grown on drylands.

Because of their longer root systems, trees are able to utilize moisture and nutrients that lie far beyond the reach of annual crops. Many of the trees that have evolved in the dry areas produce fruit crops even during the worst drought years. And properly managed tree plantations can provide good and permanent soil cover, both directly and through their litter production.

The dryland food-producing trees could also benefit the areas receiving much larger amounts of rainfall. Most of them can also be grown in more humid conditions, but they will still keep on using water very sparingly. This could be important in a situation where billions of people are already threatened with water shortages even

in areas that receive quite a lot of rain: we need to look for plants that can produce more food with less water.

It is probable that many of the trees that are likely to become important tree crops for the drier parts of the world, will come from Africa. None of the presently cultivated tropical and subtropical fruit and nut trees have originated in Africa. All the domesticated tropical fruits come from Latin America, Asia, the Middle East, Oceania or Australia. African fruits have never received similar attention. They have never been domesticated and bred to become new, important food crops.

So, in Africa, we are still dealing with essentially wild trees, trees that often produce relatively small fruit or fruit and nuts in which the relation of the non-edible portion and the edible portion is not very favourable for human consumption. African fruits often have a thick, inedible cover or they are full of inedible seeds. However, in the long run, Africa may have a lot more to offer than any other continent, in terms of food-producing trees that can thrive in extremely harsh and dry conditions.

First, Africa is the hottest continent and, after Australia, the second driest. It also has the oldest deserts in the world. For these reasons, Africa has, by far, the most interesting collection of wild food-producing trees that can thrive and produce food for human consumption in very arid conditions. So far humans have only domesticated two such fruit tree species: the date palm (*Phoenix dactylifera*) and the desert apple (*Zizyphus mauritiana*).

Dryland trees have not received much attention because only a few people have been living on drylands. Now the situation is changing rapidly and there is more and more pressure on drylands.

Many African dryland fruit trees produce good fruit crops even in drought years, and they have a capacity to produce huge quantities of food for humans with only a few hundred millimetres of rain per year. For example, mature mongongo (*Ricinodendron rautanenii*) trees can produce, annually, 200–600 kilograms of fruit per tree.

The nutritional value of the fruit flesh is about the same as that of maize, and the nut inside the flesh is still more nutritious. The



average production of selected adult marula (*Sclerocarya caffra*) trees is more than 500 kilograms of fruit and nuts per tree. In areas receiving 300–400 millimetres of rainfall, it might be possible to grow at least 50–60 large trees per hectare.

This means that marula and mongongo trees can produce very large quantities of food in conditions where 'drought-resistant' millet varieties only yield, on average, a few hundred kilograms per hectare. The difference in productivity is even more striking if we include the fallow years the calculations. This further reduces the statistical average annual production of ordinary fields.

In Botswana, ordinary field farming quickly depletes the fertility of the soil. After a few years of farming, the land has to be left fallow for 10–20 years. Tree crops, on the other hand, can be grown continuously, without any fallow periods. Because of the litter production of the trees, and because there is no need for intensive weeding of the undergrowth, there is very little erosion. Also, the deep root systems of the trees prevent the leaching of valuable nutrients into deeper soil layers.

The dry and hot conditions of Africa have produced a large number of fruits which have hard wooden shells (like baobab and the wild oranges, or *Strychnos* fruits). Such a shell can be seen as Mother Nature's answer to industrial canning. Most fruits with a wooden shell can be preserved for a longer time than the presently cultivated tropical fruits. For example, *Strychnos cocculoides* (monkey orange) has a shelf life of up to three months. Also, the fruits are not so easily spoiled by mechanical damage during transportation. These are major benefits for the rural people, who usually want to sell part of their fruit crop to the urban areas.

Many wild African fruits have exceptionally high calorific values. For example, the baobab fruit contains 1300 kJ/100 g. This is almost twice more than the energy value of avocado, which is usually considered the most nutritious fruit.

Different wild fruit tree species of Africa also bear fruit during different times of the year. Some of them could, therefore, be grown to provide fruit during the seasons when only a few of the presently cultivated fruit trees bear fruit.

Some of the African fruit and nut trees might also become a source of healthy food oils for Africa—and for other continents as well. Most food oils consumed in Europe and North America—and in Africa—are very unhealthy, and cause cardiovascular disease. However, the oils that contain a lot of oleic acid, like olive oil, have an opposite effect: they reduce the risk of cardiovascular disease. In the Mediterranean region, cardiovascular mortality is much less than elsewhere in Europe, and the main factor seems to be the consumption of olive oil. The use of olive oil could, in theory, prevent millions of deaths every year in North America and in Europe.

For example, marula oil is 70 per cent oleic acid. It might be possible to produce very healthy food oils in the drylands of Africa with more competitive prices than in the Mediterranean. This might have a very important impact on national health in Africa, America and Europe, perhaps even in Asia, and produce a lot of foreign currency for Africa.

It is likely that by the year 2050, the African, Asian and Latin American drylands will have to feed many more people than their present population of less than one thousand million. Food-producing trees thriving in dry conditions are likely to become an integral part of the farming systems on drylands.

Therefore, if we can identify some of the most promising candidates for new food trees for drylands and if we manage to grow them in orchards—and breed productive varieties of them—it is likely that the planting of such trees will become a very common habit among the rural populations of the drylands in Africa, Asia and Latin America.

Mango is not indigenous to Africa, but because it has a very tasty fruit, it has spread more or less spontaneously over the whole continent, so that large areas of Africa are now a kind of 'mango savannah'. All the other trees have been cut down and you can only see mango trees for miles and miles and miles. Similarly, bananas and papayas have spread, more or less spontaneously, to practically every village and every household in areas where they can be grown.

Something similar might happen with the new desert fruit and nut trees as well. With mangoes, the process took several centuries. Today similar things are likely to happen much quicker: the gov-



## How the Coconut Got its Face

A young man from Kerala, born into a fisherman's family, did not know how to catch fish. He tried every way, with poles and nets, but he never caught any fish and got poorer and hungrier. Everybody in his village laughed at him. So he decided to learn some magic. He went to a teacher of magic and learnt how to remove his head from his body.

When the beach was deserted in the evenings, when all the fishermen had returned to their villages with their daily catch, he would come to the beach and, in a secluded corner, take off his head from his trunk and dive into the water. The fish had never seen such a strange sight and they always clustered around. All the small fish entered his body through his neck. The man would then swim ashore, take the fish out, and replace his head. He would go back to his village and show the villagers all the fish that he had caught.

He told no one his secret. The villagers, who saw no poles or nets in his hut, nor caught sight of him at the beach, grew exceedingly curious. One day, a little boy followed him to the shore. He saw him take off his head and dive into the water. The little boy darted forward and snatching the head, ran away. After a few yards, he found it too heavy and threw it into a bush.

The man came out of the water and could not find his head. He searched all over and then, because his magic was running out, he threw himself back into the sea and became a fish.

The little boy brought all the villagers to show them the miracle of the head. But when they came to the bush near the sea, they found that it had already grown into a tall and slender palm with nuts on it. Each nut had the man's face on it. And thus the coconut tree was created.

*—A folktale from Kerala*

ernmental agricultural and forestry extension services, as well as the tens of thousands of non-governmental organizations promoting tree planting, will do their best to promote the adoption of the new trees.

However, most people do not want to eat only fruits and nuts. Most people want bread and porridge, so we need to find trees which thrive in arid conditions and which produce something that can be ground to easily usable and tasty flour.

## Rainforest Regions

In the super-humid tropical rainforests, the topsoil contains practically no nutrients: all the nutrients have been washed down to the deeper soil layers by the heavy rainfall. Most of the available nutrients are contained in the vegetation itself, and they are continuously being recycled by the trees. If the trees are replaced by annual crops or by pasture, most of these nutrients will be lost in a very short period of time.

When the land is transformed to pasture, it is usually cleared by burning. This creates a transient fertility that will wear off in a year or two. After this, the land is invaded by weeds, many of which are poisonous to cattle. The only practical way to fight the weeds is to burn the area again, but the repeated burnings further deplete the fertility of the soil.

After another three to five years, the land has to be abandoned, and left fallow for a much longer period of time. And a substantial part of its fertility has been lost on a permanent basis: because all the trees have been cut down, most of the nutrients have leached into the deeper soil layers, so that they can no longer be captured even by the trees that will grow on the land during the fallow period. Slash-and-burn agriculture can also produce a similar degradation of the land, if the burning and cultivation periods become prolonged, or if they are repeated too often.

The answer, again, is to mix perennial crops with annual plants. If there is, permanently, a large enough number of trees growing on each hectare of land, the nutrients will not be leached into the deeper soil layers. Instead, they will be captured by the innumerable small branches of the trees' root systems and recycled back to the farming system.


As long as the rapid recycling of nutrients, the actual basis of the whole rainforest ecosystem, is maintained, crops can be grown on rainforest land on a permanent basis, for thousands and thousands of years. In theory, it should be possible to continue this kind of cultivation even much longer than this: some rainforests have probably existed for a hundred million years or more.

If cultivated by conventional farming methods or turned to pasture, rainforests are among the world's poorest and most unproductive lands. However, when multi-storey home gardening in practised, and a permanent tree cover is maintained, they can be extremely productive, because of the combination of high temperature and extreme humidity. Tropical rainforests are situated in areas that would anyway receive a lot of rain, but in some cases the amount of rainfall is doubled or multiplied by the trees. Huge amounts of water evaporate from rainforest trees. At the same time, they produce aerosols (tiny particles) that contribute to rapid cloud formation over the forest. Researchers have found that some rainforest areas have an ability to circulate up to 75 per cent of the rainwater back to the atmosphere. This superefficient, superfast recycling of nutrients (and water) leads to very high biological production.

In one study, the natural rainforest of Panama was found to produce about 40 tonnes of fruit (with a net dry weight of eight tonnes) per hectare in a year. This is a lot, when we remember that not all the trees growing in the rainforest produce fruit.

At its height, the Mayan civilization supported populations of 700–1150 people per square kilometre on rainforest land in the densely populated parts of their empire. According to Clive Ponting:

> Excavations in the outer areas of Tikal suggest that, at its height, the population was at least 30,000 and possibly as high as 50,000 (of the same order as the great cities of Mesopotamia). Other cities, though not quite so large, would have followed the same pattern of dense urban settlements and so it seems likely that the total population in the Maya region at its peak might have been near to five million in an area that now supports only a few tens of thousands.

The descendants of the ancient Maya, the Lacandon Maya Indians, still practice simplified forms of the methods that made these rather impressive population densities possible.

Lacandons clear small plots inside the forest, the size of which is usually more or less around a hectare. The felled trees and branches are left on the ground in order to prevent erosion and to reduce leaching of the nutrients into deeper soil layers. Fast-growing tree-like perennials like banana and papaya are planted immediately after the clearing of the forest, in order to reduce the loss of nutrients. Other fruit trees like guavas, plums, custard apples, pineapples, cacao, avocados and citrus fruits are also planted. In an old plot that is just cleared again for farming, there will already be a number of fruit trees. On the trunks of the trees, climbers like yams are grown, and maize, cassava, sweet potatoes, rice, sugarcane and other crops are planted between the trees.

The Lacandons do not concentrate certain plants in separate compartments in tidy straight rows. On the contrary, they make a point of not planting clusters of the same plant species within three metres of the same variety. The idea of this practice is to minimize the spread of plant-specific pests and diseases and to make the best use of the available nutrients.

In conventional western-type gardening, it takes a lot of work to keep the spaces between different crops clear of weeds. In the Lacandon system, there are no spaces between food crops, because every square inch is covered by different crops that are grown on purpose. This does not eliminate the need for weeding, but reduces it in a very significant way.

The same plot is cultivated from three to seven years in a row. After this, weeds become a major problem, and the land is left fallow for five years or more. After the fallow period, it is again cleared for farming. But even during the fallow period, the fruit trees growing on the plot continue producing food for human consumption.

A Lacandon Milpa the size of 0.4 hectares can produce two and a half tonnes of maize and an equivalent amount of tree and root crops in a year. In the same area, cattle-raising produces a maximum of 10–50 kilograms of meat per hectare, annually.



The Lacandon system already gives us a vague idea of what could be done if the rainforest lands were cultivated in a somewhat similar way.

However, the Lacandon system is not the optimal system we should have in mind. It should be relatively easy to develop multi-storey rainforest gardening systems that are still much more productive. The Lacandon Mayas only grow relatively small fruit trees in their Milpas, and many very productive and promising food-producing trees like peach palms, ingas, breadfruits, jackfruits and plantains are unknown to them.

According to C.R. Clement and H. Villachica, Amazonian peach palm cultivation can yield up to 30 tonnes of fruit per hectare, annually. In other words, peach palm plantations can produce between 500 to 2,500 times more protein and calories suitable for human consumption than cattle-ranching. And this is a short term comparison: in the long run, the difference is still more dramatic, because cattle-ranching can typically be continued for five or seven years only, before the land has to be abandoned.

A patch of rainforest growing (mostly) selected varieties of leguminous trees might annually yield much higher crops of edible pods than those that have been achieved in temperate regions. The hectare yields might well amount to 100 tonnes or even more.

## Tropical Wetlands

Indonesian peatlands can contain, on one hectare, almost one hundred times more carbon than the rainforests surrounding them. When a peatland area is ditched and transformed to agricultural land, the peat reserves start to decompose, releasing huge amounts of carbon dioxide into the atmosphere.

According to studies done in Indonesia, the draining of tropical peatlands for agriculture typically releases about 30 tonnes of carbon per hectare per year into the atmosphere. This can go on for a long time while the peat is slowly disintegrating, layer after layer.

There are, altogether, about 150 million hectares of tropical peatlands. If a major part of them are drained and transformed into conventional agricultural land, they could make a major additional

contribution to greenhouse gas emissions. In many cases, the draining of the peatland areas can also cause other problems. Peatlands and other types of wetlands often play a key role in replenishing the groundwater resources. If they are ditched, the water table may decline. In some areas, peatlands also slow down the flow of water, releasing it gradually into the rivers, thus storing huge quantities of water for the dry season. Without peatlands, the dry season flows of rivers would be reduced in many areas.

Another alternative would be to use the tropical peatlands to cultivate plants that grow naturally on them. Such plants can be grown without draining the surface of the peatland. In many cases, the best form of land-use could be the mere management and utilization of the natural vegetation—like sago or nipa palm stands; in other cases, palm forests could be established in areas where there is a lot of pressure to transform peatlands into agricultural lands.

This kind of land-use would not cause additional carbon dioxide emissions. On the contrary, the amount of carbon that would annually be stored in the peatlands, could probably be increased if suitable management and cultivation practices were to be developed for tropical peatlands. Second, the palm forests growing on the peatlands could also produce a lot of fuel that could replace fossil fuels: fuel alcohol, biogas or charcoal made of fruit covers, as well as palm leaves and stems.

Other benefits would include the protection of numerous wild bird and mammal species (the dense native palm forests form excellent shelter for wild animals). The possible detrimental impacts of ditching on groundwater resources or on the dry season flows of rivers would also be avoided.

Besides the actual peatlands, there are also other types of tropical wetlands. Mangrove swamps—which are one of the natural habitats of the nipa palms—deserve special attention. There are still about 24 million hectares of mangrove forests, but they are among the most endangered ecosystems in the world. According to one estimate, Africa has probably lost 55 percent, and Asia 58 per cent, of their mangrove trees. This has had very serious consequences for the people who depend on fishing for their livelihood.



Commercial prawn farming has become one of the most important reasons for the destruction of the mangrove forests. Prawn farming increased fourfold during the years 1985–1994, and the annual value of exports climbed to about US$ 8 billion. However, the social and ecological impact has been disastrous.

In West Bengal, research has shown that more than 90 per cent of the marine fish species found in the region spend one or more periods of their life cycle in the mangrove forest, and it seems that many of the species cannot survive without mangroves. In the Gulf of Mexico, it has been estimated that 97 per cent of the commercially valuable fish species are dependent on coastal wetlands, and that the annual fish catch has been reduced by 2.5 tonnes for each hectare of destroyed salt marshes (the temperate equivalent of the mangrove forests).

In Thailand, 100,000 hectares of mangrove swamps have been cleared for prawn farming. This has caused the loss of up to 800,000 tonnes of fish in the natural catches. According to the proponents of prawn farming, this has been amply compensated for by the 120,000 tonnes of prawns that have been produced in the area that used to be mangrove forest. In monetary terms, 120,000 tonnes of prawns may have more value than 800,000 tonnes of fish—but from the viewpoint of the fishermen, or of the poorer segments of the population, the situation may seem different. Prawns are predators that are fed by pellets made of fish-meal. About one tonne of pellets is usually required to produce 170 kilograms of prawns. This means the further loss of seven tonnes of fish for each hectare converted to prawn farming.

However, even this isn't the whole story yet.

Mangrove forests also catch and stabilize sediments brought by rivers and thus effectively create new coastal land areas. The destruction of mangrove forests causes accelerated erosion: without the mangroves, large land masses can simply disintegrate and be washed out by the sea. This means that the clearing of mangrove forests is perhaps the single most significant threat to coral reefs, which also have major importance for marine fisheries. In the Philippines, the cutting of the mangrove forests in Bacuit Bay increased the load of

sediments on the coral reefs by 200 times. Five per cent of the corals died during the first year after the cutting had started.

It is difficult to estimate how much fish is lost because of the increased sedimentation due to mangrove forest destruction, but the damage could be substantial. According to researchers of the Philippines Marine Science Institute, up to 20–25 per cent of the combined fish catch of the Third World countries comes from the coral reefs. Mangrove swamps also protect coastal areas from floods caused by tropical hurricanes or typhoons. In Malaysia, it has been estimated that it would cost up to US$ 300,000 per kilometre to replace the mangroves by stone walls.

Because the farmed prawns are confined in large numbers in small artificial ponds, there is a need to pump more salt water into the ponds in order to keep the stock alive. Salt water often leaks to adjoining farming lands causing salinity. It can also leak into the water table, and contaminate the drinking water of the local people. Intensive prawn farming is not sustainable in the long run. After 5–10 years, the farmers usually run into serious problems and have to abandon the ponds. After this, they move to new, unpolluted sites—if they can.

There are between 15–20 million traditional fishermen in the world, besides which many people earn their livelihood from selling fish or working in fish factories. When the family members also are included, it has been estimated that between 150 and 200 million people earn their living, or a major part of it, from fishing. If the present trends continue, many of them could soon be out of work.

Perhaps the worst way to utilize the mangrove forests is to clear them for prawn farming. It would be far more advisable to grow nipa or sago palms in them, together with the mangrove trees, and utilize such semi-natural stands for the production of starch, sugar and edible fruit. This kind of harvesting would not endanger the important biological functions of these forests.



## High Mountains and Northern Regions

The world's mountainous areas cover an area of about 30 million square kilometres and are home to about 600 million people.

In steeply sloping hills and mountains, topsoil is quickly lost if annual crops are planted without complex terracing systems. The fertile topsoil layer, accumulated during tens of thousands of years, may be washed away in a few decades.

Besides terracing, this problem can be avoided by using suitable combinations of perennial crops (trees and shrubs) and annual crops. Trees thrive on steep hill slopes, even in places where hardly any soil can be seen. Their roots can penetrate deep into small cracks in the rock to acquire the necessary nutrients and moisture. Trees and bushes grown on densely planted rows along the contour lines can also capture soil and thus create, little by little, level terraces on which other types of crops can be grown also. Or, alternatively, trees can be used to stabilize more conventional terraces, in order to reduce the heavy maintenance work on them.

Thousands of years ago, ancient Greece had already lost almost all its topsoil due to intensive farming and grazing. After this the Greeks started to grow olive trees on eroded mountain slopes where other crops could no longer be grown. This saved the economy of the Greek civilization. Tree crops could become as important for most other mountain ecosystems as well.

One option that is yet to receive the attention it rightly deserves, is cooperation between the northern areas and the high mountain regions of the Hindukush-Himalayas and Andes. The climate cools, on average, by half a degree Celsius for each additional 100 metres in altitude. A place one kilometre above the sea level should be roughly five degrees Celsius cooler than a coastal plain. This means that many crops that grow on high mountains could also be grown in the northern regions—and vice versa.

Such cooperation might, in the very long run, have major importance for the whole of humanity. During the peak of the last Ice Age, the northern glaciers covered most of north and central Europe, Canada and the northern parts of the USA. Southern Europe and most of China and the USA were treeless tundra. The northern

border of the boreal forest zone cut through India and southern China.

This kind of situation will be repeated again, sooner or later. During the last two or three million years, the climate on earth has been characterized by the alternation of warm interglacial periods, usually lasting 15,000–20,000 years, and slightly longer glaciation periods or ice ages. This periodical alternation is likely to continue for tens of millions of more years.

Human civilization was born and has flourished during our present interglacial period, which has now lasted for about 12,000 years. In spite of the greenhouse gas emissions, it is almost certain that this warm interlude is not going to continue for ever. After a few thousand years, the glaciers will again begin their march towards the south and bury vast areas under two kilometres of ice. At the same time, the tundra and northern evergreen forest zones will also shift towards the south, and tropical and temperate areas will contract to small nuclear patches from their present much larger size. Most of humanity will then have to feed itself with crops that can tolerate severe cold and which can be grown in the climatic conditions of the northern evergreen forest zone.

A number of such species can be found in the northern regions, but they are much more numerous in the high Andes and Himalayas. From this perspective, specific attention should perhaps be paid to the food-producing trees and other food plants growing on the southern slopes of the Himalayas, in India, Nepal and Pakistan.

In the areas where the trees and other plants had a clear escape route—a continuous land mass which enabled them to withdraw farther to the South while the glaciers marched forward—glaciation periods did not do too much damage: species could fall back in a relatively good order. For example, in North and South America, this was the case: because the Rocky Mountains and the Andes form the spine of the double continent in the north-south direction, they did not block the escape routes of the tree and plant species. Even then, the numerous back-and-forth changes in the climate favoured species that spread and matured quickly. This led, for example, to the near extinction of the redwood family.

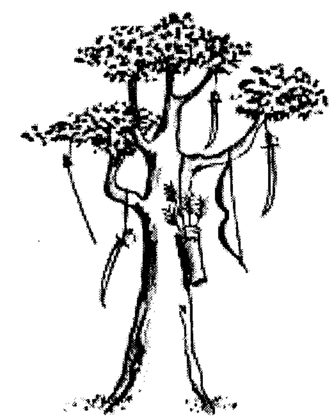


## How the Pandavas' Weapons Were Saved

In South Asia, the shami tree (*Prosopis spicigera*) has major cultural importance. *Prosopis* in Greek means 'obscure'. *Spicigera* is taken from Adrian von der Spiegel, a physician of the sixteenth century. The Sanskrit word *shami* means pod.

The Vedas endowed the shami tree with the property of containing fire. A Rigvedic legend says that Pururavas, the ancestor of the Lunar race of kings, which included the Kurus and Pandavas, generated the primeval fire by rubbing the two branches of the shami and asvattha (*Ficus religiosa*) trees together.

The shami tree is revered because Rama is supposed to have worshipped it before he set off with his army to recover Sita. Among the Rajputs, the chief or king goes in procession to worship the tree on the tenth day of Dashera and liberates Jay, the sacred bird of Rama. In the Deccan, the Marathas shoot arrows at the shami tree on the same day and put the falling leaves into their turbans. It is also considered one of the abodes of Shiva. One of Shiva's names is *Shamiroha* or 'one who ascends the shami tree'.



The Bharvads of Gujarat make their marriage posts of the branches of this tree, believing it to be the home of the dreaded ghost Mamo, or maternal uncle. In Punjab, when the bridegroom goes to fetch his bride home, he cuts down a branch of this tree. The intention is to intimidate the evil spirits that abide there and who are alleged to interfere with wedding rites.

One of the most famous legends related to the shami tree is from the Mahabharata.

The Pandavas lost everything to the Kauravas in a game of dice between Yudhisthira and Duryodhana. The latter promised that he would return their kingdom to the Pandavas if they stayed in the forest for 12 years and incognito for another year. If they were recognized during that last year, they would have to repeat their exile.

After 12 years in the forest, the Pandavas came to the kingdom of Virata and decided to disguise themselves and live in the court of the king there. Before they assumed their disguises, they took off their weapons, given to them by various gods, and hung them on a shami (*Prosopis spicigera*) tree. They found a corpse close by and suspended it from the branches, saying that 'this is the body of our mother. It must remain here for a year, after which we shall take it down and burn it.' So, of course, no one dared to touch the weapons. When they returned a year later, still unrecognized, they found the weapons safe in the branches of the shami tree.

Before taking their weapons down, the Pandavas worshipped the tree to thank it for keeping their weapons safe. When the Pandavas won the battle of Kurukshetra, the worship of the shami tree on Dashera day became a custom that is followed to this day.

*— from the Mahabharata*

In areas where the escape routes were blocked by high east-west mountain ranges, the results were more dramatic. In central and northern Europe (where the Alps and the Carpathian mountains created an insurmountable barrier) and in western Siberia (where the escape routes were blocked by the Altai and by the Hindukush-Himalayas) a great majority of plant and tree families were wiped out by the glaciation periods following one after another.

For these reasons, the vegetation in eastern Siberia is much richer in plant and tree genera than that in western Siberia or Europe. The same applies to the southern parts of Hindukush-Himalayas, when compared with the areas that are situated north of these mountain ranges.

There are about 200 species of wild trees and about 120 species of wild shrubs producing edible fruits, nuts and berries that grow on the mountain slopes of the Hindukush-Himalayan region. This is much more than what is found in north Europe or Siberia. The domestication of these species could benefit both the people living in the Hindukush-Himalayan region, the peoples of the Andes and the people living in Russia and other northern countries. During the next glaciation period, they could be of major importance for the whole of humanity, and provide humans with a major part of their food for 50,000 or 100,000 years.

### Mycoforestry: An Underground Revolution?

Mycorrhizae are fungi that form an association with the roots of a tree or another kind of perennial plant. There are two main types of mycorrhizae. One group is called the endomycorrhizae. Endomycorrhizae can invade the tissues of a plant and grow inside them. The second type—which we are interested, in here—are the ectomycorrhizae. The ectomycorrhizae form a kind of mantle around the roots of trees and plants, including the very smallest ones, but they are external and do not penetrate the insides of the roots.

Mycorrhizae form a symbiotic relationship with trees. They take sugar from the trees but assist them in acquiring nutrients and moisture from the ground, so the relationship is mutually beneficial.



According to the latest estimate, there could be 13 million species of fungi in the world, but only a tiny fraction of them are ectomycorrhizae. Ectomycorrhizae produce growths that consist of innumerable spores (tiny, asexually-produced 'seeds'). Such growths—or sporophores—are often so small that they cannot be seen by the naked eye. Many species produce their sporophores under the ground.

However, thousands of ectomycorrhiza species produce larger, above-ground growths that contain their spores. Such growths are commonly known as mushrooms. Some mushrooms are deadly poisonous. Some are not poisonous but still inedible. Some are edible but so small that it would be too much trouble to collect them for food. Some are edible but very rare. Some are edible and produced by tree roots in large quantities.

In rainy years, Finland's 26 million hectares of forests can produce four or five million tonnes of edible mushrooms. Most of the crop consists of different mycorrhizae. During such wet years, the average hectare yield can rise to 200 kilograms of wild mushrooms. In the 1970s there were four years like this. In dry years, the average yield could be around 1.5 million tonnes.

Recently clear-felled areas produce very little mushrooms because there are no trees to support the mycorrhizae, and because the unprotected soil heats up too much during the summer time. While the forest grows older, the yields of mycorrhizal mushrooms tend to rise and diversify. In Finland, the annual hectare yields of wild mushrooms can exceed two tonnes on the best sites. Temperate regions produce even better yields. An old German study estimated that the average annual mushroom yield in the German forests was more than one tonne per hectare, five times more than the yield in Finland in good years.

The calorific value of fresh mushrooms is rather low (on average 150 kJ/100 g) because they contain a lot of water. But a notable part of their dry weight consists of protein, which increases their nutritional value. They also contain different minerals, and some species are rich in vitamin D.

Even though the natural yields of edible mycorrhiza mushrooms can be impressive, it might be possible to multiply them with proper

forest management practices. The Coalition for Environment and Development (CED), the research and development cooperation organization of the Friends of the Earth Finland, has coined the term 'mycoforestry' for various practices aiming to increase the natural yields of edible mushrooms.

In the natural forests of Finland, certain sites produce good crops of mushrooms every autumn, except in very dry years. For example, a single root of an old birch tree growing near one of the research sites of CED has, in most years, produced several kilograms of mushrooms. In the autumn of 1997, this single tree root produced 10.4 kilograms of mushrooms within an area of only a few square metres. The mushrooms constituted an impressive line along the root. However, the same tree had dozens of other large roots and there were other big trees growing nearby. Even though the external conditions related to factors like soil fertility, nutrient content and moisture should have been similar, the other roots of the same tree and the roots of the nearby trees produced hardly any mushrooms.

The most probable explanation for this is that only a small minority of all the tree roots growing in the Finnish forests have formed a symbiosis with a mycorrhiza that regularly produces good crops of edible mushrooms. The endomycorrhizae, that do not grow mushrooms, are probably more common than the ectomycorrhizae, and only some of the ectomycorrhizae produce larger mushrooms.

If it were possible to increase the percentage of trees (or tree roots) growing mycorrhizae that regularly produce good crops of edible mushrooms, mushroom yields could probably be increased in a very significant way.

In the tropics, this kind of management practice could—at least in theory—increase the mushroom yields even more than in the northern and temperate zones. An estimated 95 per cent of all tree species in natural tropical forests are mycorrhizal exclusively with endomycorrhizae. This means that the remaining five per cent of tropical trees that can also form a symbiotic relation with ectomycorrhizae-producing edible mushrooms offer a notable additional benefit that the other species do not have. Such species should perhaps be given special attention in the planning of various agroforestry and multi-storey home garden systems.



However, textbook information about which species are exclusively endomycorrhizal should be treated with caution. People interested in mushrooms have said that many tree species that are officially supposed to be exclusively endomycorrhizal sometimes seem to form a symbiosis with an ectomycorrhiza, and produce good crops of mushrooms. Based on such anecdotal evidence, we might assume, that there are at least some (and perhaps very many) tree species that prefer endomycorrhizae and normally form a symbiosis with them, but which are, in suitable circumstances, also capable of adopting an ectomycorrhiza. Sometimes it could be a question of who gets there first.

Mycorrhizal mushrooms could be an important additional product in all humid and sub-humid ecosystems in the temperate, subtropical and tropical regions. In the more humid areas, mushrooms could be produced continuously throughout the year. In the sub-humid areas, they would only be produced during the rainy season, but the quantities might still be significant. Mushrooms can be dried in the sun and stored for long periods of time, so they can be eaten during the dry season as well.

The most attractive aspect of mycorrhizal mushrooms is that they do not replace other forms of land-use but complement them. Besides providing an additional product in the agroforestry systems, mycorrhizae could increase the wood or fruit production of the trees, instead of reducing it.

Some of the tropical and subtropical forest ecosystems are dominated by clearly ectomycorrhizal species. Such forest ecosystems include the dipterocarp forests of south and Southeast Asia and the savannah woodlands dominated by trees belonging to the cassia (*Caesalpinioideae*) subfamily of leguminous trees in Africa. In the miombo woodlands in Tanzania, only 20 per cent of tree species are ectomycorrhizal, but they constitute more than 60 per cent of the wood volume of the natural forests. Trees with ectomycorrhizae probably attain, on average, a larger size than other kinds of trees.

Because some mycorrhizal mushrooms command a high price in the North American, European and Japanese markets, several countries have experimented with the growing of mycorrhizal mushrooms. However, it has turned out that this is far from easy. Myc-

orrhizal mushrooms can be grown in sugary solutions in laboratory conditions, but their growth without the mother trees is painfully slow, and they are very vulnerable to attacks by bacteria.

Besides the laboratory experiments, people have, during the centuries, done their own experiments. They have often tried to establish new growths of popular mycorrhizal mushrooms in their backyards or homesteads by throwing pieces of them on the ground or burying them near the tree roots. Every now and then this may have produced the desired results, but most often it has not. When a tree seed germinates and begins to produce roots, it is almost immediately attacked by the closest mycorrhizae. After this, the mycorrhiza that has conquered the root keeps it tightly wrapped and defends it against other mycorrhizae. Therefore, the newcomers are not able to establish themselves unless they happen to land on seeds that have not yet started to produce roots.

Perhaps the most successful programmes have been carried out by Japanese and French scientists, who have been able to establish growths of certain mycorrhizae into the roots of tree seedlings before they have been planted. This has produced mushroom yields that are substantially higher than the natural yields. Also, the African researchers working in ICRAF's (International Center for Research in Agroforestry) research station in Zomba, Malawi, have been able to establish mushroom-producing mycorrhizae into the root systems of Mmilo (*Vangueria infausta*) trees before planting.

However, these trials have used technologies and techniques that require research laboratories, and which cannot be replicated in the village level by the people themselves.

The Coalition for Environment and Development (CED) has mainly been interested in methods that do not require expensive equipment and can easily be replicated by any villager. To find out whether the semi-cultivation of mycorrhizal mushrooms is possible with such methods, CED has organized field trials to test the feasibility of some (theoretically) promising techniques.

However, because both the trees and the mycorrhizal mushrooms that occupy their root systems grow very slowly in the northern conditions of Finland, it will take a long time before the trials actually produce any useful information. It would, therefore, be a good idea to establish similar trials, testing the same methods, also in tropical and subtropical regions, where the trees can grow 10 times faster than in Finland.



CED has been interested in four different sets of methods which might have wide applicability at the village level. The first method is to identify the trees whose roots (one or several large roots) have clearly formed a symbiosis with a mycorrhiza that produces valuable mushrooms. In most cases, it is not possible to say exactly what tree has produced certain mushrooms. But in some cases, the mushrooms grow in neat clear lines along the roots of a certain tree, so that you can even deduce the pattern of branching of the roots from the lines of mushrooms.

In this method, a patch of commercial forest is carefully investigated before it is thinned. The trees that are clearly growing valuable mushrooms in their roots are marked and left standing when the other trees are felled.

When the surrounding trees are cut down, most of their root systems and the mycorrhizae growing in them die. At the same time, the trees that are left standing expand their root systems because they will suddenly have access to more nutrients, more water and more light. The mycorrhizae producing edible mushrooms should expand with the root systems of the remaining trees, and conquer more ground from other, less fortunate fungi.

If the forest regenerates naturally, from the seeds or root suckers of the trees that have been left standing, there is also a very good chance that many of the new trees will select the valuable mycorrhizae and integrate them into their root systems.

A small number of old trees with valuable mycorrhizae could be left standing permanently on each hectare of land. If they remain there for centuries, while the consecutive crops of younger trees surrounding them are cut down, the old giants would spread their root systems and the mycorrhizae growing in them over the whole area. In such a system, there should be, generation after generation, more edible mushrooms. Because some of the larger trees would remain standing, this kind of land-use system would also have major benefits from the viewpoint of carbon sequestration and nature conservation, not to mention aesthetic values. In an ideal situation,

## The King and the Drum

Once upon a time in central India, there lived a king who was handsome but very vain. He looked at himself constantly, in mirrors, in pools of water, even in other people's eyes when they spoke to him. 'I am the handsomest king on earth,' he said to his courtiers. He paid less attention to ruling his kingdom than he did to having his hair styled and his body oiled. As a result, his people grew poorer and unhappier.

But the king did not care. 'Why!' he boasted one day in court. 'I am probably more handsome than all the gods.'

Unfortunately for the king, a particularly bad-tempered god happened to be flying by and was incensed at what he heard.

'Something will have to be done about this king.' He searched in his mind for an appropriate punishment. Then his eyes fell upon a bull. 'Horns!' The god clapped his hands with malicious glee. 'I will see how His Handsomeness likes himself with horns.'

When the king awoke the next morning, he followed his normal routine. First he drew his mirror out from under his pillow and gazed into it.

Suddenly the guards outside the king's chamber heard a loud shriek. They came rushing in to find the king sitting upright in bed with a large pillow on his head.

'Out...out...' he waved a trembling finger at them. As they backed away, he shouted after them, 'Send for the royal barber immediately.'

The royal barber was a cheeky, talkative little man. He came in briskly.

'You're up early today, Your Majesty, but why the pil...'

The king broke in, 'Stop your patter and come close to my bed.'

As the surprised barber drew close, the king said in his most commanding voice, 'Barber, I am about to show you something. But if you talk about it to a single living soul I will have you flogged and hanged.' The king slowly removed the pillow from his head.

'Oh!' The barber clapped his hands to his mouth in horror.

'Well, don't just stand there,' said the king impatiently. 'Do something to cover them up.'

The barber tugged the king's hair this way and that and managed to cover the horns partially. The king put his nightcap on to hide the rest. 'Now go and tell the court I am unwell. I will not see anyone.' He sat up and glared at the barber. 'And remember my warning.'

The barber fled. As soon as the door of the bed-chamber closed he started laughing. The palace people stopped him and asked him the reason for his mirth, but the barber only shook his head helplessly and ran laughing through the halls.

'I will die if I don't tell someone,' he groaned. 'My stomach is welling with the secret.'

He saw the tamarind tree standing in the middle of the royal courtyard. He went up to it and whispered the secret to its trunk.

That night there was a fierce storm and the tamarind tree was blown down. The king was informed through the door, for he would not see anyone, and he commanded the tree to be given to the royal musician. 'Let him make a drum from the trunk of the tamarind and play it outside my door.'



Soon the drum made of tamarind wood was ready. The courtiers assembled outside the king's door and the musician began to play. But instead of the thum thum thum that everyone expected, the tamarind drum intoned, 'The Raja has horns on his head. The Raja has horns on his head.' The court burst out laughing, and the king cried with rage.

'I won't stay in the palace a moment longer,' he shouted, 'I'll go to the forest and live by myself.' He tore the nightcap off his head and ran out of the palace, seizing the tamarind drum on his way out.

The king lived for several years in the forest. He learnt about the beauty of the world around him. He learnt to care for creatures smaller than himself. He grew strong and wise and selfless. His only companion was the tamarind drum and the drum, when he beat it, gave him all the advice and experience of the old tree. He learnt to play it so beautifully that even the spirits of the trees were charmed and they went to meet the god who had given him the horns.

'Forgive him,' they pleaded. 'He has changed. Remove his horns and give him back his kingdom.'

The god waved his hands and the horns disappeared.

During the day the king went down to a forest pool to drink water. While cupping his hands he saw his reflection, and his lean, sun-tanned face looked back at him, without any horns. And, as he sat up in surprise, several horse-riders burst into the clearing and he saw his courtiers. They knelt before him. 'Your Majesty, forgive us and come back. The kingdom needs you.'

The king went back to his realm. He kept his tamarind drum beside him always and he ruled wisely. And yes, the barber kept his head, but lost his job!

most of the remaining old trees would be species that also produce fruits, nuts, pods or seeds that are suitable for human consumption, besides the mushrooms.

Needless to say, when the stands of the young trees are thinned, trees that are clearly growing the desired mycorrhizae in their root systems should be given preference over other trees. Through such practices, it should be possible to produce notable increases in the yields of edible mushrooms.

Another set of methods investigated by CED concentrates on identifying natural forest sites that are clearly dominated by certain mushrooms, and by germinating seeds or root cuttings at such spots. If a certain square metre of land is producing two or three kilograms of certain mushrooms—and no other mushrooms can be seen at the same spot—it is very likely that the seeds or cuttings planted at this spot will pick up the same mycorrhiza. After the seedlings have grown some roots, they can be removed and planted at other sites. Ordinary layering could also be tried. The shoots used for this could come from the shoots of the trees growing in the same place, or they could be shoots of plants that are brought to the site in pots.

One of the problems with these methods is that the best mushroom sites in the forest often have too much shade. Another problem is that it is obviously not possible to produce large numbers of seedlings with such methods.

A third set of methods involves the production of seedlings (from seeds or cuttings or through layering) in sterilized soil. The idea is, first, to kill all the mycorrhizae in the soil by heating, and then introduce large amounts of the desired mycorrhiza spores. If the sterilized soil is soaked and mixed with crushed pieces of mushrooms, the seeds or cuttings producing roots in the soil are very likely to pick up the right mycorrhiza.

Perhaps the easiest way to sterilize the soil so that all the mycorrhizae are killed is the method developed by the Zambian-Botswanian researcher Stanley Mateke, working for the Veld Products Research and Development (VPRD). The trick is to fill part of a steel barrel with water, after which a steel net or a sieve with a very small eye-size is put on top of the water. The soil that is to be sterilized is then laid on top of the steel net. A small fire is lit under the barrel for eight hours, and the steam produced by the fire kills all the germs and fungi in the soil.



Through this method, it might be possible to produce a larger amount of seedlings which have the desired mycorrhiza mushroom in their root systems.

CED is also investigating the propagation of trees from root cuttings that contain a desirable mycorrhiza. Many tree species can be propagated from root pieces. If a root is clearly producing a valuable edible mushroom along a length of three or four metres, we can cut the root to small pieces and grow a new tree from every piece. If we manage to choose pieces of root that are mantled by the desired mycorrhiza, we might be able to propagate these mycorrhizae with the tree. Through this method, it might be possible to produce trees whose every major root will be covered with the same mycorrhiza. The mycorrhizae should grow together with the new root systems!

If this method works in the trials, the establishment of new clones of aspen that grow a certain valuable mushroom in their root systems will become a very tempting option. Some of the aspens growing in the Rocky Mountains probably are more than a million years old. Individual stems do not live more than 150–200 years, but the root system that links the stems together is almost eternal. If we were able to produce aspen clones that produce valuable edible mushrooms in all their major roots, such clones might still be around a million years from now. They could perhaps produce food and other benefits for 50,000 future generations of human beings.

Many of the ideas described above could be a bit new. It is possible that some of them have never been tried before. Therefore, it is not possible to guarantee that the methods described above will work. It is possible, and it might even be plausible, that they will work with a certain statistical probability, but there is no certainty about this before we get the results of the first trials.

However, we warmly urge you to join us in conducting experiments along these lines. It is not difficult, and in the annexes there are some more practical instructions on how you might design your own investigations. You can still be one of the world's first mycoforestry researchers.

There are lots of things to study. There are thousands of edible mushrooms, many of which can form a symbiotic relationship with numerous different trees. Many others, however, are always associated with only a certain tree species.

In this book, the importance of mycorrhizal mushrooms has been emphasized because they can be grown together with living trees. However, we should not forget the rot fungi (fungi that get their nutrition through the decomposition of wood and other plant matter) and mushrooms produced by them.

Rot fungi have been cultivated by humans for thousands of years and by termites and ants for a very long time, probably more than a hundred million years. The fact that the combined weight of both the termites and of the ants exceeds the weight of the planet's human population says something about the potential of such farming systems.

At the moment, rot fungi do not play a major role in the world's food production, even though growing them is easier than the growing of mycorrhiza mushrooms. The methods that have been in use are somewhat complicated and the original investment costs, often a bit high. In most of the present systems of intensive mushroom cultivation, the temperature and moisture levels have to be monitored and controlled carefully in order to ensure a good crop.

It is also possible to develop low-cost methods of rainfed rot mushroom cultivation that do not require heavy investment. Like the mycorrhizae, the rot fungi could also form an additional component in the agroforestry systems, without competing with other types of production. They would not even compete with the mycorrhizal mushrooms.

When a tree falls down or is cut, the wood in the stumps, roots, branches and trunks that are left on the ground will always decay within a number of years. The wood is eaten by various microorganisms and fungi: it is only a question of what kind of fungus will do the job.

Most rot fungi do not produce edible mushrooms, but some of them do. Whenever the forest is thinned or logged, or some individual trees are felled, it might be a good idea to drill a hole into each stump and install some fungal root growth of a desirable rot



fungi. This would ensure, that the right type of rot fungi would invade most of the stumps and major roots of the felled trees. Some species of rot fungi can produce 300–600 kilograms of edible mushrooms for each tonne of dry matter they decompose. About one-third (and often more) of the biomass of the trees is often underground, so the mere stumps and roots of the felled trees can actually produce rather handsome crops of edible mushrooms.

In the northern forest zones, individual tree stumps that have caught the right fungus often produce amazing crops of edible mushrooms for a decade or two. CED has also initiated a number of field trials, in which all the stumps of the felled trees in the experimental areas are treated in the above-mentioned way. The final aim is to develop an agroforestry system that would simultaneously produce large amounts of timber and fuelwood, fruit, nuts and berries, mycorrhizal mushrooms and rot mushrooms. The new trees that will be planted between the old stumps have been treated with mycorrhizal fungi, and the stumps are used in the cultivation of rot mushrooms. The older trees that start to produce especially good crops of mycorrhizal mushrooms are never felled, until they start dying of natural causes.

## The Big Trees of the Oceans

The oceans too have their giant trees. The sequoias of the sea are called giant kelp. They are algae that can reach lengths of 70 metres or more. Individual fronds do not live for a very long time, but the holdfasts, the rootlike clumps of strands that attach the plant to the bottom, can be relatively long-lived. The holdfasts of the giant kelp can sometimes be up to three metres thick.

Giant kelp, some other species of algae and a number of other water plants grow faster than any other plants in the world. Giant kelp can grow 60 or 70 centimeters in one day, and up to 130 centimeters per day if the upper parts of the fronds are being harvested. The daily growth of the water hyacinth mats in sweet water can amount to 25 tonnes of wet biomass or 800 kilograms of dry matter per hectare. Eucheuma seaweeds can increase their weight by 5–11 per cent in one day.

It has been estimated that humanity can, at the moment, catch only 1/2500 of the oceans' biological production in the form of fish. This is because we mostly eat fish that have eaten smaller fish that have eaten animal plankton that have eaten smaller animal plankton that have eaten phytoplankton (tiny floating plants). The food chain or food net of the ocean is normally very long and complicated, which means that a great majority of the production is wasted, from the human viewpoint.

By growing edible seaweeds, it would be possible to cut all or most of these extra links from the food chain, and to increase the production of food for human consumption in a very important way.

Many people in Asia, especially the Chinese and the Japanese, cultivate a number of edible seaweeds for human consumption. In the former Soviet Union and Norway, several different seaweed species used to be harvested and ground to flour. The algae flour was then mixed with ordinary bread flour in order to add some more protein and nutrients to it. Algin extracts made of giant kelp are used by the food industries in California.

However, the possibilities are limited by the fact that the very shallow sea waters where seaweeds grow naturally only cover a tiny part of the oceans. The seaweeds are dependent on sunlight and can only grow relatively close to the surface of the sea.

The Gandhian inventor, C.V. Seshadri, proposed some time ago, that simple floating fish-aggregating devices should be installed in shallow waters along the entire coastline of India. The devices would have benefitted small fishermen by increasing their catches and by deterring modern trawlers from fishing in the shallow waters, for fear of entangling their trawler nets.

Such fish-aggregating devices spread along the coastline within a kilometre or so from each other might also—at least in theory—enable people to use up to 30 million square kilometres of shallow seas for the cultivation of edible algae. These drowned parts of the continental shelves constitute less than 10 per cent of the oceans' combined area, but are responsible for a major part of their biological production.



The fish-aggregating devices could, perhaps, be linked to each other with complex systems of ropes (besides being anchored to the bottom). The ropes could be set so that they do not float, but sink to a depth of five, 10 or 20 metres. Pieces of soaked wood, coconut hulls, stones, large seashells or things of this sort could perhaps be tied into the ropes, and small seedlings of edible seaweeds could be rooted on them. With some species, it would even be possible to merely cut a piece of the stem of the seaweed and tie it to the rope by a smaller string. When the crop is to be harvested, the rope can be drawn closer to the surface so that the upper part of the seaweed can be cut off.

Another option would be to use slightly modified forms of a method that has often been used by Indian fishermen to attract fish, and to sink whole trees (with branches!) into the bottom of the sea. The trees could be anchored into the bottom with rocks so that they would stand in an upright position, crowns towards the surface. If edible seaweed would be planted on the branches of the trees, a few underwater trees like this could give us one more hectare of marine seaweed farming area. The obvious limitation of the method is that the deeper the water gets, the longer the trees would have to be in order to enable the seaweeds to grow.

## Health Aspects of Tree Crops

The most important factor influencing people's health is their nutritional status. People who have inadequate diets are much more likely to suffer from or die of communicable diseases than people who have been adequately nourished. When the quantity and variety of food available in Europe increased in the nineteenth century, the mortality rates—especially infant and child mortality—also declined.

The death rate from tuberculosis had already declined to one-eighth of the previous level before the first effective medical treatment for the disease, streptomycin, was discovered. Similarly, infant mortality caused by measles had, in the industrialized countries, dropped to one in a thousand before the measles vaccination was developed. Before the vaccines, the mortality rate due to measles in Mexico used to be 180 times higher than in the USA. In Guatemala, it was 268 and in Ecuador 480 times higher.

There are currently about 1,200 million people suffering from hunger in the world. If we also count the people suffering from deficiencies of vitamins or other important nutrients, the number rises to two or three billion.

Tree crops can increase food production. They can also diversify and improve the quality of the food that is being produced. For example, many fruits, berries and edible tree leaves contain large amounts of vitamins and other nutrients.

Vitamin A seems to be especially important. Eighty to 90 per cent of children in many southern countries suffer from vitamin A deficiency. The United Nations Children's Fund (UNICEF) has estimated that vitamin A deficiency doubles infants' risk of dying of acute respiratory infection, which annually kills four or five million babies. It was recently discovered that lack of vitamin A also increases malaria mortality. In a study done in Papua New Guinea, it was ensured that all children got enough vitamin A. This reduced malaria mortality by 30 per cent. Adequate supply of vitamin A also seems to reduce the death rate caused by diarrhoeal diseases.

In the beginning of the 1980s about a million children were annually blinded by xerophthalmia, caused by a lack of vitamin A. Various governmental and non-governmental health and education programmes have now improved the situation, but hundreds of thousands of children still lose their sight because their diet does not contain enough vitamin A.

Most of the edible oils currently consumed in the world are very unhealthy ones. They contain a lot of saturated fat that contributes to the development of cardiovascular diseases. While the people in industrialized countries are becoming more aware of the issues related to food and health, people in most Asian, African and Latin American countries are rapidly increasing their consumption of dangerous animal fats. The World Health Organization (WHO) has estimated that unless these trends change, the annual mortality caused by cardiovascular disease in Asia, Africa and Latin America will rise to 14 million by the year 2020, most of which will consist of clearly premature deaths.

Many trees like olives, avocados, marula and mongongo produce fruit and nuts that can be used to make healthier, mono-unsat-



urated fats. Such food oils can actually contribute to the prevention of cardiovascular diseases, instead of causing them.

Besides vitamins and nutrients, fruits also contain large amounts of dietary fibres. It has been proven that a diet with an adequate fibre content significantly reduces the risk of several types of cancer. A diet that includes a lot of fruits also reduces the risk of cardiovascular disease.

The so-called antioxidants are compounds that slow down or prevent certain harmful chemical reactions in the tissues of our bodies. It seems that they have a very important role in preventing cardiovascular disease and cancer. Our bodies produce their own antioxidants, but we can also acquire more through our food. The antioxidants produced by plants are called flavonoids. Many fruits and berries, as well as red wine, are rich in flavonoids, which means that they probably assist our bodies in fighting off cancer and cardiovascular diseases.

Water polluted by different pathogens and disease vectors living in water cause between five and 10 million deaths every year. Sometimes, the best way to provide pure water for people is to use natural coagulants that can purify the water efficiently. For example, an extract made from the seeds of horseradish tree (*Moringa* spp) or the seeds of the desert date (*Balanites aegyptica*) is used in this manner by many African tribes. The same technologies might have a wide applicability in other areas too, where it may be, for some reason, difficult to provide people with clean water. Another important solution is to boil the water, but this is only possible if the poorer households have access to solar cookers, or have an adequate supply of other kinds of cooking energy.

Wood and biomass fuels also have important health implications. For at least a million years, humans and their ancestors have been cooking most of their food with wood. About three billion people in the world still use wood, straw and cow dung as the source of their cooking energy. About one quarter of the people who use fuelwood for cooking live in India.

Studies have linked fuelwood smoke to an impressive number of ailments. They include acute respiratory illnesses like bronchitis and pneumonia (both among children and elderly people); lung can-

cer and a number of other cancers; chronic lung ailments like asthma chronic obstructive lung disease and emphysema (and the heart problems that are often related to such lung diseases); tuberculosis; severe coronary heart disease; adverse pregnancy outcomes, like an increased risk of low birth-weight, stillbirth or neonatal death; eye diseases and anaemia.

A survey carried out in Jumla, a cold mountain district of Nepal, where the average indoor smoke levels are very high, reported an infant mortality rate of 490 per 1,000, 335 of which were due to acute respiratory illnesses. The very high infant mortality rate in the area is most probably caused by woodfuel smoke. Studies made in western India have estimated that the exposure of pregnant women to woodfuel smoke increases the risk of stillbirths by 50 per cent. In Nepal, 15 per cent of non-smoking women suffer from chronic bronchitis.

According to the World Health Organization, smoking by pregnant women doubles the possibility of the children being born underweight. This, in turn, increases the babies' risk of dying during their first year of life by three or four times. There is no reason why exposure to smoke from cooking would not cause similar damage to the unborn child.

According to one estimate, particulate air pollution from the fuelwood smoke is, in India, responsible for 900,000 to 3,600,000 deaths, annually. Another study has estimated that outdoor air pollution in the Indian cities is responsible for 40,000 to 50,000 deaths annually, while the smoke from cooking stoves kills 2.2 million people in a year. If the mortality rates among the other three-quarters of the people who use such fuels for their cooking are somewhat similar, the impact of the fuelwood smoke becomes one of the most important health problems in the world.

In China, where much of the cooking is done on small stoves burning mineral coal instead of charcoal, mineral coal is probably causing similar adverse health effects as the burning of biofuels in open stoves has been reported to causing. In spite of all this, it has been estimated that more than 99 per cent of the world's air pollution research and control expenditures concentrate on reducing outdoor air pollution—which is responsible for less than 40 per cent of the total worldwide human exposure to particulates.



One solution to the problem is to spread the use of smokeless *chulhas*: if the stoves are equipped with a flue (chimney) through which the smoke can escape, exposure is greatly reduced. Such cooking devices can be made of clay or mud to reduce the cost, so that even the poorest families can afford them. Another simple solution is to improve the ventilation of the kitchen. According to Indian scientists, if a roof hatch the size of one square metre can be opened when food is being prepared, it can reduce the exposure to smoke by almost 90 per cent.

Paradoxically, to increase the production of good-quality fuelwood might also be one of the easiest and cheapest ways to improve the situation. The worst alternative is to burn cow dung or very small and moist branches and sticks. When the burning temperatures are low, a lot of different toxic compounds are produced. Also, the agricultural production suffers, because the cow dung would have great value as fertilizer. It is important to dry the wood properly before burning. Finnish studies have shown that the burning of moist wood can produce a hundred times more dangerous particulate emissions, compared to properly dried wood.

Proper firewood produces less smoke and less toxic compounds than cow dung or small sticks. Also, some species of trees are better suited for firewood than other species. Their wood burns cleanly and produces only little smoke. Unfortunately, it is the poorest who are forced to use the worst firewood: the better fuelwood is often too expensive for them. More extensive growing of high-quality firewood would be a partial solution to the problem.

Charcoal produces much less harmful emissions than fuelwood. Most of the harmful particulates and other toxic compounds are released during the charcoal-making process. Because of this, charcoal burns quite cleanly, even though it can produce high carbon monoxide emissions if the burning is not complete enough.

However, charcoal is more expensive than fuelwood. Another problem is that it is often produced by simple earth kilns that waste up to 90 per cent of the energy value of the wood. Part of the loss is

compensated for by the fact that charcoal is more efficient to use than wood. Because it burns well, it can be used in smaller quantities and in a more economic way than wood. This reduces the amount of wastage by a factor of two or three. Improved charcoal kilns can preserve up to 70 per cent of the wood's energy content, but they are, in most cases, too expensive for the poor charcoal makers. The development of improved earth kilns, as an intermediary stage in the charcoal production technology, might be a partial answer to the dilemma.

From the viewpoint of public health, the use of biogas, fuel alcohol or solar cookers are still better alternatives. For example, nipa palm stands could annually produce about 11,000 litres of fuel alcohol per hectare, but it would probably still be too expensive for the poorest families. In South Asia, the average cost of a biogas generator sufficient for the needs of one family, has been about US$ 200, which is also very expensive for low-income households. Some of the new models developed in Vietnam cost only US$ 20, which is already much more affordable. Besides cow dung and human waste, the Vietnamese biogas generators, which are, in practice, large plastic bags, can also use food waste, crop residues and other plant matter.

Solar cookers are even cheaper. Many models cost US$ 20–40, but it is also possible to construct a solar cooker that only costs around one rupee. Such a one-rupee-solar-cooker can be made, for instance, by taking some mud, clay or cow dung and by moulding it to a parabolic shape (the shape of a satellite antenna). Besides this, only some thin aluminium foil and some glue is needed. When the aluminium foil is glued on the parabolic-shaped base, it will act as an efficient reflector that concentrates the sun's rays on a pot that is hung over the cooker.



## Why the Leaves of the Tamarind are so Small

Long, long ago, when both gods and demons walked the earth, Bhasmasura was the chief of the Asura or demon army. He challenged Mahadeo or Shiva, the god of destruction, to a duel. The winner, it was decided, would become the ruler of the earth. Mahadeo took up the challenge.

The two fought and Bhasmasura was wounded several times. He ran for his life, fleeing through the forest looking for a place to hide. Then he saw a tamarind tree with huge spreading branches and giant leaves. Mahadeo found that the demon had vanished. He looked everywhere and as he passed under the tamarind tree Bhasmasura shifted nervously and the leaves rustled. Mahadeo looked up. He knew his enemy had been found, but he couldn't see him. He tried with one eye, then with both, but the leaves hid the demon from sight.

Mahadeo's patience was exhausted. With a roar of rage he opened the magical third eye in the centre of his forehead. Each leaf disintegrated into small pieces. Mahadeo saw Bhasmasura and killed him. The earth was saved from the demons, but the leaves of the tamarind have always remained small.

*—A Sambalpur tribal legend*

# 2

# Cooling the Globe with Trees

GLOBAL WARMING IS rapidly becoming the single most serious threat to the future of humanity. According to climate scientists, the emissions of carbon dioxide, methane and other greenhouse gases might increase the average global temperatures by 1.5–6 degrees Celsius in the twenty first century.

According to the International Panel on Climate Change (IPCC), an authoritative scientific body aiming to coordinate research on global warming, the higher temperatures could lead to a rise of seven to 13 metres in the sea levels during the next 500 years. If sea levels were to rise by 10 metres, about 10 million square kilometres of land and most of the world's fertile farmlands would be inundated. About half of the world's people would lose their homes to the waters. Most of our great cities would also be submerged.

The predicted rise is caused by two factors: heat expansion of the sea water and the partial melting of the Greenland and west Antarctic glaciers. According to the IPCC, the thermal expansion of the water 'would continue to raise sea levels for many centuries after stabilization of greenhouse gas concentrations'. It will take





about a 1000 years before the warming will reach the bottom of the sea, but during this time, the warming predicted for the next century could raise the oceans by four metres.

Another problem is the glaciers. IPCC scientists now predict that a rise of 2.7 degrees Celsius in temperatures in Greenland would trigger an 'irreversible' melting of its ice sheet. This would raise sea levels by seven or eight metres during the next 1,000 years.

Some researchers claim that the west Antarctic ice sheet is also showing signs of becoming unstable. According to the latest satellite pictures, the largest glacier of the west Antarctic ice sheet, the Pine Island Glacier, is already losing ice faster than snowfall can replenish it. If the glacier continues to melt at the current rate, it will disappear in 600 years, raising global sea level by five more metres. And these five metres would come on top of the rise caused by heat expansion and by the melting of the Greenland ice sheet.

If these scenarios become true, the continuous rise in sea levels could become the single most important factor sustaining and deepening absolute poverty in the world—for 1,000 or even 10,000 years. A major part of the world's population would be pushed into the coastal areas threatened by the rising sea and by hurricanes, because no one else would like to live in these areas, and because the rich and powerful would appropriate for themselves all the good farmland in safer regions. When the sea levels would rise, little by little, the poorest people would have to escape and move, over and over again, losing their homes and a major part of their scarce properties each time.

In Bangladesh, about 10 million people are already living like this: the poorest families have been pushed on lands that will sooner or later be swallowed by the great rivers that are continuously changing their courses. Many families have been forced to move more than 10 times, and each time they have been forced to construct new huts for themselves—which has eaten away whatever little money they have been able to save.

The areas that lie on somewhat higher ground would also be likely to suffer. Various extreme weather conditions like floods and droughts would become more common. The incidence of devastating typhoons and hurricanes might increase by a factor of 10, if the

world becomes five degrees warmer than now. At the same time, the destructive power of the worst storms might increase by 50 or 60 per cent because of the higher temperatures—and higher wind speeds caused by them. This would be very bad news for the countries that are suffering from typhoons or hurricanes. A major hurricane or typhoon can already now wreck the economy of a whole country for decades. Super-hurricanes created by global warming would do still more damage.

Besides the rise in sea levels, the most serious consequence of global warming could be the drying of the tropical and subtropical areas. Even though rainfall is likely to increase, evaporation would increase even more. According to one estimate, a four-degree rise in global temperatures would increase rainfall by an average of 12 per cent and evaporation by 30 per cent in the tropical and subtropical areas. This would most probably cause a disastrous decline in agricultural yields, unless the emphasis is shifted to crops that do not require much water.

According to the second IPCC report of the drying, the tropics might reduce the flow of the Nile by 75 per cent, which would be a catastrophe for Egypt and its neighbours. Many other large rivers in India, Pakistan and China—including the Indus—would also suffer because of the increased evaporation rates.

A further threat comes from the melting of the Himalayan glaciers. The quantity of water in the Himalayan glaciers is not large enough to raise the sea level in a significant way, but the issue is extremely serious because of other reasons. If the snow and ice masses in the Himalayas continue to melt, the water supply of much of Asia will be affected. The Indus, Ganga, Mekong, Yangtze, Huangho and many other major rivers get most of their dry season flows from the Himalayan glaciers.

It has been predicted, that the Himalayan glacial area alone will shrink by one-fifth within the next 35 years, to 100,000 square kilometres. In the last 50 years alone, some 15,000 glaciers have already vanished in the Himalayas. The Gangotri Glacier of the Indian Himalayas—the source of the holy Ganga—is now retreating at an average speed of 30 metres a year, compared to 18 metres a year between 1935 and 1950 and only seven metres a year between



1842 and 1935. The Pindari Glacier is now retreating at an average rate of 135 metres a year. Indian scientists have projected that by the year 2030 many of the rivers originating from the Himalayas, including the Ganga, Kali and Indus, to name a few, will all be dry during the dry season.

These are grave predictions, especially because the groundwater resources in South Asia, Southeast Asia and China are also being depleted at a frightening speed.

Many tropical diseases that require high temperatures would spread with the increasing temperatures. For instance, global warming might greatly increase the number of people that are threatened by the deadliest form of malaria, *Plasmodium falciparum*, and by schistosomiasis. Falciparum malaria is already killing three million people every year, and the situation is getting worse because the malaria parasites are rapidly developing strains that are resistant to most of the known medicines. At the same time, the mosquitoes that spread the parasites are becoming resistant to pesticides.

Schistosomiasis already affects 250 million people, and causes permanent damage and disability to many of the carriers. Large parts of Asia, Africa and Latin America have thus far been spared the problem, because their winter temperatures have been too low for these parasites. But this could soon change because of global warming.

According to the IPCC, the world has probably already warmed by 0.6 degrees Celsius because of the greenhouse gas emissions from the burning of fossil fuels and from the destruction of tropical forests. This might be only 50 per cent of the warming we have already committed ourselves, by emitting carbon dioxide and other greenhouse gases into the atmosphere. According to the IPCC, a certain increase in the concentration of greenhouse gases in the atmosphere will, in the long run, warm the global climate by a certain number of degrees. But because the oceans warm only very slowly, at a much slower pace than the atmosphere itself, there is a long delay before the whole impact is actually realized. In other words, even if we eliminate all our greenhouse gas emissions today, it is possible that the climate would still go on warming by another 0.6 degrees.

The most frightening possibility is the so-called runaway greenhouse effect. Thus far, the oceans, soils, peatlands and forests of the earth have absorbed a significant part of all the greenhouse gas emissions. This has slowed down the warming process. But many scientists are afraid that, if the climate warms too much, the global warming will start to feed itself—in other words, to accelerate.

It is possible that the oceans can be transformed from a carbon sink to a source of atmospheric carbon dioxide: if their surface temperatures are warm enough, they may start to release carbon instead of absorbing it. Similarly, the soils could be transformed from a carbon sink to a new source of carbon dioxide emissions. If the areas covered by ice and snow in the northern latitudes are reduced, this could also trigger a feedback loop, because snow and ice reflect sunlight much more effectively than soil or vegetation.

In the worst case, the result might be a kind of vicious cycle. The more carbon dioxide is released from the oceans, the more the climate heats up. And the more the climate warms, the more carbon dioxide is released.

Large areas of the continental slopes and the sea bottom are covered by thick layers of mud. The typical thickness of these sediments is a few hundred metres, but it can sometimes be more than two kilometres. The average carbon content of the sediments is about eight per cent. This means that truly enormous amounts of organic carbon have been stored in these sediments during the time life has existed on earth.

Unfortunately, a part of this organic carbon has been stored inside the sediment layers in a potentially dangerous form. Inside the mud there are large quantities of methane gas trapped within ice. Such compounds are called methane hydrates or clathrates. The Russians found the clathrate deposits a few decades ago when they were looking for new sources of commercial energy.

Nobody knows exactly how large the methane clathrate deposits are. The lowest estimate is 10,000 billion metric tonnes, but the largest quoted estimate is 1000 times larger. The smallest estimate is equivalent to 2000 times the current amount of methane or 15 times the amount of carbon dioxide in the atmosphere. This is potentially worrying, because methane is 63 times more effective as a greenhouse gas than carbon dioxide, and because a lot of methane could be released from the sea bottom if the sediment layers warm so much that the methane ice starts to melt.



Russian scientists have already reported methane plumes hundreds of metres wide, that have come bubbling to the surface on the Sea of Okhotsk, off the coast of Sakhalin Island. Scientists have also found traces of vast, prehistoric methane eruptions from the sea bottom. About 8,000 years ago, some 5,600 cubic kilometres of sediments slid a distance of 800 kilometres from the upper edge of the continental slope into the basin of the Norwegian Sea. This vast landslide was most probably triggered by the melting of methane clathrate deposits, due to the warming of the sea. The scientists have also found 700-metre-wide and 30-metre-deep craters, created by explosive releases of methane from the bottom of the Barents Sea.

According to this theory, a runaway greenhouse effect would only stop by itself when the climate reaches a new state of equilibrium.

We do not know whether a runaway greenhouse effect is a real possibility. In any case, it is probably the most serious environmental catastrophe that could possibly happen. In the earth's long history there have been a number of astonishingly rapid shifts in the climate. It sounds plausible that these extremely rapid changes, that have sometimes taken place in a few decades—which is, in geological time, only a blink of an eye—have been caused by a combination of different positive feedback loops, or, in other words, by a kind of natural runaway greenhouse effect.

The Governments have still been dragging their feet in the global climate convention negotiations. There has been the utmost reluctance to take the issue seriously. The oil, coal and gas industries and the manufacturers of aircraft and automobiles have spent large amounts of money lobbying against any measures aimed at curbing greenhouse gas emissions. They are, in effect, gambling with the future of human kind, not to say anything about the other species on our planet.

This is very irresponsible, to say the least. It has already become obvious that we have to move away from fossil fuels to biofuels, wind, solar, geothermal and hydrothermal energy—and to other

renewable sources of energy. Besides this, we have to abandon the idea of a global marketplace and reduce the amount of goods that are transferred to us from other continents by freightships or, which is the ultimate madness, by an aircraft. We have to renew the local economies so that a majority of everything we need—including our food and clothes—can be produced as close to home as possible. This would basically mean taking Gandhiji's vision about strong but somewhat modernized local economies (*Gram Swaraj*) seriously.

According to the conventional breakdown, the transport sector is responsible for about one-third of the consumption of fossil fuels in the industrialized countries. However, a Spanish study concluded that when the indirect energy use of the transportation sector is also included, it is responsible for more than half of the fossil fuel consumption. The study also included in the transportation sector the energy used to manufacture cars, planes, ships and trains; the energy used in building docks, airports, roads, multi-storeyed car parks and other infrastructure, as well as the energy required to produce the packing materials that become necessary because of the longer transportation distances.

The greenhouse gas emissions caused by the transportation sector in the industrialized countries have increased significantly over the last 40 years. This has not happened because more goods are being consumed, but because roughly the same weight of goods is being moved over longer distances due to increasing concentration of production—which is also causing large-scale unemployment. In Britain, the number of freight-ton miles almost tripled between 1952 and 1992, even though the production of most bulk commodities fell.

The larger the economic units or 'free trade areas' grow, the longer the average transportation distances of various goods become. The United States of America is the only continent-wide modern free trade area that has existed for a somewhat longer time. It might not be a coincidence that the per capita carbon dioxide emissions of the USA are almost three times higher than that of Japan or western Europe. The USA annually produces about six tonnes of carbon emissions for every inhabitant of the country.



If the whole world were to become a truly global free trade area, so that all the goods were to be produced wherever they could be manufactured at the cheapest possible price, and then transported to the other side of the world, the carbon dioxide emissions caused by humans would multiply, and there would be no hope of preventing the melt-down of the Greenland ice sheet or the drying of the Tropics.

On the other hand, if we can make our countries abandon the madness of the present neoliberal free trade policies that are destroying both our environment and hundreds of millions of jobs, we can cut the world's carbon dioxide emissions in a very significant way. This can be done simply by strengthening local economies and by protecting different national and local production in agriculture, forestry, fishing, handicrafts and village industries.

However, all this will inevitably take some time. To make things worse, it seems that there is already too much carbon dioxide and other greenhouse gases in the atmosphere. The Himalayan glaciers are already melting at an alarming rate and the melting the west Antarctic ice sheet has already begun, according to recent satellite pictures. And it seems that the climate would still go on warming for some time, even if we eliminated all the emissions today, because of the delay caused by the exchange of heat between the atmosphere and the oceans.

Therefore, it seems that, besides reducing future emissions, we also have to remove some of the carbon dioxide we have already produced from the atmosphere, in order to prevent the drying of our rivers and a one-thousand-year-long rise in the sea levels. This can be done by planning and developing land-use systems that produce food, fodder, fertilizers, firewood and timber for the people—in other words, by growing trees that can attain a substantial size.

The first priority must be to stabilize the situation, to build energy production systems based on renewable energies and to cut the greenhouse gas emissions back to a sustainable level: we have to first mend the hole from which the oil is leaking into the water. However, after we have mended the leak, we should try to do something to mop away the oil that has already entered the water and which is poisoning the fish and the other animals.

## The Ancient World of Giant Trees

About four billion years ago, the earth had an atmosphere that was much denser than now. It contained perhaps 30,000 times more carbon dioxide than now. Because of the greenhouse effect created by this massive carbon dioxide atmosphere, the average temperature of the earth was probably somewhere between 240 and 340 degrees Celsius. Since then, volcanic eruptions and other volcanic processes have emitted huge amounts of carbon dioxide. In spite of this, the carbon dioxide content of the atmosphere has reduced by 99.997 per cent. Because of this, the average temperature of the earth is now only 16 degrees above zero, in spite of the fact that the sun is 30 per cent hotter than three billion years ago.

Different chemical processes started, little by little, to absorb carbon dioxide and to tie it into various minerals containing carbon. However, these processes accelerated tremendously with the beginning of life. According to one estimate, they have probably removed from the atmosphere, during the last three billion years, about 140,000 times the amount of carbon dioxide currently existing in the atmosphere. This huge amount of carbon has been stored in limestone and other minerals, in coral reefs, in coal, oil and other fossil fuels, and in the sediments of the continental slopes and ocean floors. According to scientists, the sediments of the ocean floors can be more than two kilometres thick, and roughly eight per cent of them consist of organic carbon.

The world's forests, peatlands and soil also contain large amounts of carbon. The forests currently contain roughly 500 billion tonnes of carbon. The carbon store in peatlands is probably somewhere between 500 and 1,000 billion tonnes. The litter, humus layer and topsoil have been estimated to contain 1,600 billion tonnes of carbon.

However, it is likely that the present amounts of carbon stored in the forests and soils of our planet are considerably smaller than the amounts stored before the arrival of our ancestors.

Of the 15 billion hectares of land on earth, approximately six billion are hyper-arid deserts, Arctic tundra, more or less untouched tropical rainforests, various kinds of wetlands, high mountains, glaciers or other lands whose existing vegetation has scarcely been af-



### Rama's House in the Forest

King Dasharatha of Ayodhya reluctantly exiled his son Rama to the forest for fourteen years. Rama smiled and went obediently to his new home. With him went his wife Sita and his younger brother Lakshmana.

Rama and Lakshmana looked for a part of the forest where they might be the most comfortable. They built a small hut under the shade of the tamarind tree. The tree had large leaves and these sheltered the hut from both sun and rain.

But Rama was not happy. One day he mused to Lakshmana: 'My father has sent us to this forest to see how well we cope with hardship. I'm sure he never meant us to shelter ourselves from all that the gods send us.' Even before he had finished his sentence Lakshmana, who loved his brother dearly, understood his dilemma. He drew his bow and shot a series of small arrows into the branches of the tamarind tree. The large leaves split into thin fringes which could not protect the princes from any of the elements, and so they have remained to this day.

*—From the Ramayana*

fected by men. But on the remaining, roughly nine billion hectares, the influence of the human hand has been dramatic.

In most cases, humans have greatly reduced the amount of carbon stored in forests and soils. The forest and bush fires lit by our ancestors have been burning trees and other vegetation in Africa and Australia for at least 700,000 years. The African savannah lands with relatively sparse tree cover are probably a result of repeated wildfires caused by humans: when a savannah area is protected from fire, it soon becomes a closed forest with a much thicker tree cover. The wildfires have also reduced the carbon storage in the litter and humus layers.

The clearing of forests for fields and pasture and the cutting of wood for fuel, timber and, somewhat later, for making paper, have also contributed to the thinning of the tree and vegetative cover of the earth. Grazing by domestic animals has also contributed to the process: by eating the young tree saplings, domestic animals often prevent the natural regeneration of the forest. The 300–500 million people that still earn their living from shifting cultivation, burn vast areas of forested land every year.

The earth has already lost about one half of its original forest cover. And on the four billion or so hectares that are still covered by forest, the average size of the trees is usually much smaller than what it used to be.

Practically every human civilization has produced myths and legends about huge world trees, vast trees that rose up to the heavens or which surrounded the whole world.

When these myths were born, forests growing on good soil were most probably full of very large trees. They were, especially before the discovery of iron, a real problem for humans, because the largest trees often grew on the most fertile soils that were best suited for agricultural purposes. Even with iron axes, the felling of such trees was a daunting task.

The oldest myths of humanity tell us about sacred world trees which were either gods or belonged to the gods. In these myths, the felling of such trees would have been an ultimate sacrilege.

Somewhat later, however, a very different category of tree-related myths appears. These legends tell us about great heroes who



felled the world trees and killed the horrible demons who protected them.

A famous example of such a story is the Sumerian Gilgamesh epic, which had a great influence, for example, on the older parts of the Bible, the holy book of the Christians.

The epic begins 4,700 years ago, when Gilgamesh, the king of Uruk, decides that he wants to become immortal by building a magnificent new capital for himself. In order to acquire enough construction material, Gilgamesh goes to Lebanon, which is famous for its ancient cedar (*Cedrus libani*) forests.

When Gilgamesh enters the forest he is moved to tears by the beauty of the vast cedar trees. He cries and says that he just can't destroy anything that is so magnificent, sacred and beautiful. However, a little later, the great king becomes himself again. He kills the horrible demon which protects the forest, lets his men cut the trees, and builds himself a great new capital. Somewhat later, Gilgamesh achieves his greatest victory by destroying Huluppa, the sacred world tree of the Goddess Ishtar.

The Sumerians once considered Gilgamesh the greatest hero of all humanity. But the story is also highly symbolic in a much sadder sense.

In Lebanon, there is still a small patch of old forest which has been saved from the axe by a small miracle. The forest only contains about 400 trees that are about 2,500 years old. The trees are not very tall, none of them exceeds the height of forty metres, but all of them are very thick. Many are five metres or more in diameter. It may be that the cedars that covered Lebanon during the time of Gilgamesh were still older and larger. In any case, these 400 old cedars are the last, sad remnant of a vast uniform belt of oak, beech, chestnut and cedar forests that once surrounded the whole Mediterranean Sea, covered most of central and southern Europe, North America and the Middle East, and stretched from Morocco to Afghanistan.

At present, mostly low, thorny bushes grow on these lands. Only 10 per cent of the original forest area remains, and the trees growing in the remaining patches are mostly young plantation forests.

Many parts of the ancient Mediterranean forest belt probably got substantially more rain than the cedar forests of Lebanon, so it could be assumed that they grew trees of an equivalent size to, if not exceeding, that of the Lebanese cedars. The few spared individual tree giants give us an idea of what these forests may once have looked like. At the end of the nineteenth century, there still was a vast chestnut tree, growing on the slopes of Mt. Etna, with a circumference of 61 metres. The largest known lime tree in Germany is eight metres in diameter, and the largest oaks in southern Europe are still more massive.

Three million years ago, before the beginning of the ice age, giant redwood forests grew on a wide belt that covered most of North America, Asia and Europe. Numerous periods of glaciation and the competition from other more modern plants and trees that were able to spread and grow faster, wiped these magnificent trees out from most of their natural range. At the end of the latest glaciation period, the last remaining refuge of the giant redwoods was California, where these giants still covered about 400,000 hectares.

When the European settlers discovered the redwood forests they almost could not believe their eyes, because some of the trees were 120 metres long and 10 metres in diameter. But, as with the case of Gilgamesh, their awe didn't last long. They soon recovered from their wonder and started to attack the giant trees with an almost religious fervour. Today, only small fragments of the redwood forest are left.

In northern USA and Canada, there were other giants that grew on vastly larger ranges. The Douglas fir, sitka spruce and hemlock forests covered vast parts of the continent. The largest Douglas firs growing today reach a height of 100 meters and can be almost four metres in diameter. But the Canadian scientists claim that the largest trees growing in the country used to be still larger. According to a report published by a group of Canadian scientists in 1940, the largest Douglas fir tree they had measured was 139 metres tall and had a diameter of 8.5 metres.

It may be that these figures were a case of scientific fraud, and it is impossible to check them because the trees in question have long since been cut down. But it is logical that timber-traders would have



attacked the best virgin forests first. Therefore, it is conceivable that the largest trees in a forest were cut down before anybody had the time to measure their size. Today only small patches of the virgin Douglas fir, sitka spruce, hemlock and thuja forests remain. These remaining virgin stands often contain 2,000–3,000 cubic metres of trunk wood per hectare.

The same fate has be fallen the strobus, ponderosa and sugar pine, as well as beech, oak, walnut and chestnut forests growing in the Eastern and central parts of North America.

China had already lost all its virgin forests 200 years ago, and India lost its last virgin cedar forests, growing 60-metre long giants (*Cedrus deodara*), in the first half of the twentieth century. Very little is known about the climax forests of China and India—we do not know what they were like and what kind of giants grew in them. Australia used to have vast forests growing gigantic eucalyptus trees, but the existing virgin stands are only a sad remnant.

Africa also had its own giants. In the West African rainforests, there were giant terminalia trees. The geographer, Ivan T. Sanderson, once estimated that the largest of these trees were about 80 metres tall and thicker than the largest known sierra redwoods. Today, practically nothing remains of these forests, and the largest hardwood trees were taken long before the forest that surrounded them disappeared as well.

In the drier parts of Africa, there were large numbers of huge baobab trees, the largest of which were 18 metres in diameter. The number of the baobab trees had probably been reduced, to a major extent, by the bush fires destroying the younger trees, but they were still very common until people started to make paper out of their fibres. Luckily, the strong protests of botanists saved the species from extinction, and baobab trees still dot the African landscape in many countries, even though most of the largest specimens were probably lost.

Similar stories are repeated over and over again wherever human habitation and technological culture has spread. The main differences are that in some regions the process took place earlier than in others, and in some regions the story about the destruction of the virgin forests was recorded in greater detail.

However, it took thousands of years before the victory of Gilgamesh over Ishtar was completed, and it is possible to argue that the struggle is still going on.

People in India and in the other South Asian countries still consider many trees and whole groves to be sacred, and are extremely reluctant to cut trees belonging to a certain species or trees growing in a sacred grove.

In Finland, people used to worship trees. When they killed a bear, they brought the skull under a revered tree, because they thought that the tree formed a channel through which the soul of the bear could enter heaven. Like practically all ancient civilizations, the Finno-Ugrian people also had their own sacred forests, in which it was strictly forbidden to cut down trees or even branches.

The Roman Pope, the leader of Western Christianity, dictated in 1228 that the sacred forests in Finland should be destroyed and replaced by Christian churches. However, the people were reluctant to participate in the process and did their utmost to protect the sacred forests and trees. The practice of tree worship and offering sacrifices to trees was common even 600 years after the Church had started its campaign, and these traditions have, to a minor extent, survived till our own days. At the moment, they are in the process of being revived again.

When the ancient trees were cut down, fields, pastures, thorny bushes or secondary forests replaced them. Whenever this happened, most of the carbon that was stored in the trunks, branches and roots of the trees and in the litter and humus, was released into the atmosphere as carbon dioxide. Some of this carbon dioxide was later absorbed again by the growth of the secondary vegetation. However, the secondary growth was only able to absorb a minor fraction of the original carbon storage.

When a tropical forest is cleared and transformed into a field or pasture, the amount of carbon stored in the vegetation is typically reduced between 90 and 99 per cent. Even today, the destruction of the tropical forests annually releases about two billion tons of carbon into the atmosphere, which is about 40 per cent of the carbon emissions from the use of fossil fuels.



Moreover, the litter and humus in the soil start to decompose when the forest is transformed into farmland. For example, the open savannah forests of Africa typically contain between 50 and 70 tonnes of organic carbon per hectare in their humus layer. Most of this is released into the atmosphere within a few years after the land has been transformed into a field.

When an ancient virgin forest is transformed into a much younger forest, the results are not quite as dramatic, but the basic pattern still remains the same.

Tropical rainforests can contain up to 700–800 tonnes of carbon per hectare. The average for the Amazonian rainforests is about 200 tonnes of carbon per hectare, even though large parts of these forests are not real virgin forests. However, when the forest is cleared for pasture and then abandoned, the secondary forests that emerge will only contain 20–25 tonnes of carbon per hectare.

In Finland, the commercial forests contain, on average, only 80 cubic metres of trunk wood per hectare. Their average carbon content is 34 tonnes of carbon per hectare (excluding litter, humus and topsoil), of which 17 tonnes is in trunk wood, five tonnes in branches, three tonnes in leaves and needles and nine tonnes in tree roots.

One-hundred-year-old pine forests growing on drier lands contain, on average, 350 cubic meters of trunk wood in southern Finland, about 300 cubic metres in the middle parts of the country, and about 150 cubic metres in Lapland, the most northern part of Finland. This is already considerably more than the average for a commercial forest.

Somewhat older natural forests often contain 700–800 cubic meters of trunk wood and 200 tonnes of carbon in the biomass of the trees. However, it is impossible to say what would have been the average for Finnish virgin forests. Many natural forests contain less than 200 tonnes of carbon in their tree biomass, but such forests are often not very old. Also, there are no real virgin forests left in Finland outside the very northern parts of Lapland.

Also, the carbon storage in the litter is much less in the younger forests. In a study made in the USA, Mark Harmon and his co-workers estimated that a 450-year-old Douglas fir and hemlock forest contained 125 tonnes of carbon per hectare in the litter. One

hectare of a 60-year-old Douglas fir forest only held 10–26 tonnes of carbon in the litter. Such figures relating to the carbon storage in the litter imply that old forests probably also contain much larger quantities of carbon in the humus and topsoil than the younger forests.

D.P. Turner and his co-workers have proposed a model in which the whole tree biomass constitutes, in North America, approximately 30 per cent of the total carbon store on different forest sites, of which two-thirds consists of trunks, branches and leaves and one-third of the tree roots. According to this estimate, the carbon in the topsoil, litter and humus would constitute about 70 per cent of the carbon in North American forest ecosystems, besides which a further 10 per cent would be in the form of living tree roots. In this model, the carbon store in the litter, humus and topsoil becomes greatest the older the trees become—and the larger the living biomass the trees acquire.

Finnish forest researchers have often based their calculations on the opposite starting point, and assumed that the carbon store in litter, humus and topsoil always remains the same. In other words, these carbon stores would not depend, at all, on whether the forest is clear-felled or whether it is a climax forest that has not been touched by fire for 1000 years.

It is likely that the model proposed by Turner and his co-workers is much closer to the truth, but the reality is likely to be somewhat more complex. The main problem is, that there is very little empirical research evidence on how different forestry practices and the age of the forests affects the carbon stores in humus and topsoil. For this reason, researchers have been forced to use very simplified models as a basis for their calculations.

So it seems evident that the world's forests and soils have, before the coming of humans, contained a much larger amount of carbon than today. The four billion hectares of forests growing in the world today only contain 500 billion tonnes of carbon in their tree biomass, which gives us a rough world average of 125 tonnes per hectare. Here it must be remembered that this figure is the average for all the presently existing forest types. Most of the carbon storage is in virgin rainforests. The commercial plantations only



## Buddha and the Monkeys

Once upon a time, the Buddha was born as Mahakapi, the king of the monkeys. He and his 80,000 monkeys lived on a single mango tree in the middle of a thick forest on the banks of the Ganga river.

Mahakapi told his tribe not to let a single mango fall on the ground. 'If a man tastes this fruit,' he said, 'he will want it all and he will destroy us for it.'

One day, quite by chance, a mango escaped the attention of the monkeys. It fell into the river and was carried downstream. Brahmadatta, King of Kashi, was bathing in the river. He saw the strange fruit in the water and, reaching out, he seized it. He smelt its freshness and squeezing it put a bit of the juice in his mouth.

He was enchanted by its sweetness. 'I must have the tree that grows this fruit,' he said. He ordered his courtiers to row upstream in boats till they found the tree, and he ordered his army to follow the course of the river.

Many days later, the men came to the mango tree, its branches laden with fruit. King Brahmadatta saw the monkeys. 'Surround the forest,' he ordered. 'Kill all the monkeys, otherwise they will eat my fruit.'

The monkeys went trembling with fright to Mahakapi. 'Save us, Lord,' they begged.

Mahakapi climbed a branch that stretched to the other bank of the Ganga and, springing from it, he jumped to the other side. He cut a bamboo and fastened it to the branch to make a bridge, so that all the monkeys could climb over and escape. But the bamboo was short, so he stretched out his body to complete the bridge.

The monkeys climbed over the body of their lord and escaped to the other bank of the river and away from the army.

But one monkey, Devadatta, Buddha's cousin, who had also been born in that incarnation, hated him. When his turn came to cross, he stamped so heavily on Mahakapi's back that it broke. Mahakapi was alone and in great pain. King Brahmadatta, who had been watching the great escape and felt nothing but admiration for the monkey king, had him brought down from the tree.

Mahakapi was received with honour. He was washed and oiled and his body clothed. He instructed the king on his duties to the lowest of his subjects and then, his body wracked with pain, he died. King Brahmadatta put up a shrine at the foot of the mango tree to honour the memory of Mahakapi, the king of the monkeys.

*—From the Mahakapi Jahata*

contain rather negligible amounts of carbon per hectare, due to their short rotation periods: in commercial plantations, the trees are usually cut down before they have grown very thick.

However, even though human beings and their ancestors have been reducing the carbon storages in the soil and in the forests for at least 700,000 years, they could also do the opposite. People can also increase the amount of carbon stored in the trees and soils, and bring it back to the pre-human levels. Humans could even improve upon nature, and grow forests that contain more carbon per hectare than the natural climax forests.

## Improving Upon Nature in Carbon Sequestration?

Different tree species attain different sizes, variable heights and differing trunk diameters. In a natural forest, the giant trees are usually relatively rare. In a rainforest, there could be one or two somewhat larger trees on one hectare. In the mountains of California, the giant sierra redwoods grow here and there, surrounded by smaller trees. In Africa, there can be kilometres between two baobab trees.

By increasing the number of the most valuable trees attaining a very large size—and letting them grow to an old age—we can obviously create forests that contain much larger carbon storage per hectare than the average natural forests.

For example, by growing 50 baobab trees on one hectare, we could, in time, achieve a vastly larger carbon store than that of the surrounding, more or less natural forests or woodlands.

If we assume, conservatively, that the average trunk diameter of the trees would finally be about four metres, and that the average trunk height would be somewhere around 10 and 15 metres, we would get almost 10,000 cubic metres of trunk wood per hectare. When the branches, roots, litter and humus are also counted, this could mean about 2000 tonnes of carbon on one hectare. Such a plantation need not be a monoculture, because there is plenty of room for smaller trees and vegetation between the baobab trees. By growing uniform stands of coastal or sierra redwoods or Montezuma cypresses, still larger per hectare carbon stores could be achieved.

However, our thesis probably holds water even if the relative shares of the various tree species in the vegetation are not altered.



The forests of Finland are an illuminating case, in this context, because 95 per cent of the woody vegetation consists of three species only. These three species are the Scots pine (*Pinus sylvestris)*, the Norwegian spruce (*Picea abies*) and the silver birch (*Betula pendula*). This astonishing lack of diversity is a result of the combined impact of numerous glaciation periods and almost 100 years of commercial forestry.

The largest amounts of trunk wood found in the natural forests in Finland have been around 700–800 cubic meters per hectare. These forests typically contain a relatively small number of large trees per hectare. Between the larger trees there can be either smaller trees and other vegetation, or even relatively large empty spaces.

Managed forests growing the same tree species achieve this kind of level relatively quickly. Seventy-year-old spruce forests growing on fertile soil can already contain 600 cubic metres of trunk wood, which is only slightly less than the amount found in the best natural forests.

The explanation for this is very simple. In a well-managed forest, there are no empty spaces: each hectare of land contains the optimum number of trees of a certain size. Also, in the thinning of the forest, the foresters preserve the best and fastest-growing trees and cut down the ones that are not performing as well. The same process would also take place in a natural forest, but only at a much later stage.

This means that the best-growing trees suffer a lot from competition for water, light and nutrients with other trees during their most rapid and vital period of growth.

For these reasons it is logical that a planted or naturally regenerated, well-managed forest should reach the typical maximum carbon store of the natural forests relatively quickly.

However, it is somewhat difficult to find conclusive proof for this, because the managed forests are usually cut down immediately after the trees have reached the minimum size of a timber tree. Because the growth of the trees begins to slow down when they get older, landowners prefer to use as short a rotation period as possible. For this reason, it is very difficult to find any planted or intensively managed forests that would be considerably older than

100 years, except on marginal soils or on very cold areas where the growth of the trees is stunted and slow.

In Finland, there is only one notable exception to this rule. In the Punkaharju ridge, there is a small larch forest that was planted in the 1870s near a forest research station. When this forest was 110 years old, some parts of it contained 1,200 cubic metres of trunk wood, if the fallen trunks are included as well.

Close to this area, on the Russian side of the border, there is a still more interesting patch of larch forest that was planted in 1738. When the forest was 257 years old, one part of it contained an amount of wood that was equivalent to 2,000 cubic metres per hectare. This was 2.5 times more than the present record for natural forests in Finland—and 25 times more than the average for commercial forests.

In the USA, the average wood volume of the old-growth redwood forests is 400 cubic metres per hectare. It may be that the best forests with the largest hectare volumes have been logged first, so that the still existing old-growth forests are not a very representative sample of the original splendour of the ancient redwood stands. One old-growth redwood stand contained more than 3,500 tonnes of above-ground tree biomass per hectare.

However, coast redwood grows faster than any other conifer, and one of the planted redwood forests already contained almost 2,000 cubic metres of wood at the age of 137 years, which is five times more than the average for all the still existing old-growth stands.

So there is an interesting paradox here. The commercial forests contain, on average, very little wood and carbon per hectare, because they use very short rotational cycles and because a large percentage of them consist, at any given time, of clear-cuts and patches of young seedlings. However, it seems that if a planted or managed forest is allowed to grow for a longer period of time, for one hundred or for several hundreds of years, it will grow a much larger store of organic carbon than a natural climax forest.

The evidence that we can, at present, mount to support this hypothesis is, admittedly, still a bit thin, so we cannot claim that the hypothesis has been proven true in a conclusive way. We can only say that the empirical evidence we have been able to gather, thus far, points towards this direction. We are very interested in and grateful for all pieces of evidence that can be used to assess the validity of the hypothesis. If you have information concerning old plantation forests, their ages and their present wood volumes, we would be most interested in such knowledge.



In Finland, for example, it is difficult to argue conclusively that somewhat older planted forests contain more carbon than virgin forests, because there are no virgin forests left in the country for several centuries, with the possible exception of northern Lapland.

For example, the Scot pines can live for 800 years, and even though there is not much growth in height after the age of 150 years, the growth of trunk diameter continues as long as the tree remains alive. Therefore, it could be argued that the virgin forests may have contained substantially larger amounts of wood than the oldest currently existing natural forests.

In northern Lapland, there are some very old forest stands which might even be classified as virgin forests, and which contain 300–400 cubic metres of trunk wood per hectare. This implies that the virgin forests in the southern part of the country should have contained more than 600–800 cubic metres of wood. Also, virgin forests growing in the Himalayan-Henghuan mountains in conditions that are in many ways similar to those of Finland, typically contain 1,000–1,200 cubic metres of trunk wood per hectare.

In other words, we don't know for sure, and there is no way we could find out quickly, but our best guess at the moment is that planted or managed forests can produce still larger carbon stores than natural climax forests.

It is possible—even though this admittedly is a very heretic thought—that even the carbon store of the tropical rainforests could be increased from what it is in the natural state of the forests. As stated above, the tropical rainforests can contain a maximum of 700–800 tonnes of carbon per hectare. However, the average is much lower, possibly somewhere around 200 tonnes per hectare.

This is, actually, surprisingly little, because we know that even plantation forests in the northern forest zone can achieve at least five times higher figures.

The explanation to the puzzle is simple: most of the rainforest trees are rather small, with girths of less than one metre. The larger trees, the emergents that can rise 15 or 20 meters above the surrounding trees, are dotted here and there in the forest. Such trees can sometimes be very large: geographer Ivan T. Sanderson has remarked that some of the rainforest giants might actually contain larger volumes of wood than the largest remaining sierra redwood specimens. But the real giants are exceptions, and even the somewhat larger trees are sparse: there are usually only a few of them in one hectare.

An agroforestry system growing, for example, 60 or 70 Brazil nut trees on one hectare, among smaller trees, would probably contain more carbon than an average hectare of totally untouched rainforest.

In the long run, the carbon stored in the root systems of the trees could also become important. The possibility of trees absorbing atmospheric carbon dioxide into the root systems has not received much research attention, because this kind of underground carbon storage is difficult to measure. There is very little information available on the issue.

The amount of carbon stored in the trunks, branches and leaves of trees cannot be increased indefinitely. There is, inevitably, an upper limit for the amount of carbon you can store in the trees and other vegetation on one hectare.

The same probably also applies to those parts of the trees that lie under the ground. The roots will decompose sooner or later, and release their carbon dioxide back into the atmosphere. But in very arid, very cold or very wet conditions, it might take a relatively long time before the roots decompose completely.

This might be the case especially in the very cold or very arid regions where the decomposition of organic material is hindered by the low temperatures or by lack of water. The further down the roots penetrate, the more likely it will be that a part of their carbon content will remain stored for some time in the deeper soil layers.

The drier the area, the larger is the proportion of the total biomass of the trees likely to be below the surface. According to Timo Karjalainen, the carbon content of the root systems in the boreal



forest seems to be slightly less than the combined biomass of the trunks, branches and leaves of the trees. But in the arid regions, the carbon storage of the root systems can be much larger than the amount of carbon stored in the trunks and branches.

The trees surviving in the arid and semi-arid areas often have pillar-like root systems that can sometimes penetrate up to 60 or 70 metres down into the deeper soil layers in search of water. According to the Guinness Book of Records, the roots of a wild fig tree are reported to have penetrated to an astonishing depth of 120 metres in the state of Transvaal, in the Republic of South Africa. By coincidence, the original maximum height of the largest known sierra redwood, before it lost its crown, has been about the same.

It is only possible to grow a limited number of trees on one hectare at the same time, because the trees compete with each other for nutrients, water and light.

But when you replace the old trees with younger ones, and plant the seedlings on new sites, they grow their own root-pillars under these new sites. If the decomposition of such root systems takes a lot of time in arid conditions, it might be possible, during a number of growing cycles, to grow *thousands* of narrow but very deep 'root-pillars' below the surface of one hectare of tree plantation, before the oldest root systems have totally decomposed.

If we were able to make the trees grow root systems that penetrate 120 metres below the surface, we would, theoretically, have 200,000 cubic meters of storage space for atmospheric carbon dioxide under each hectare of arid land.

At the moment, no one really knows how much carbon would remain stored in the ground for how long—but it should be possible to find out. One method might be to cooperate with suitable mining operations. It should be easy enough to analyze what comes up, to see how much is left of the tree roots, and how long they have stayed in the ground, in different depths and in different climatic conditions.

It would, of course, be utterly impractical to grow long-rooted trees on vast areas of drylands, only to absorb carbon dioxide into their root systems. But such carbon sequestration impacts are likely to be a spontaneous additional bonus from the efforts to breed new

food-producing trees for drylands: food trees growing on arid lands usually have long roots.

Thus far, human interventions have tended to reduce both the amount of biomass above the ground and the amount of carbon stored in the root systems.

Even in the tropical rainforest, tree roots may contain much higher amounts of organic carbon than has been assumed. It has often been claimed that in the Amazon, 90 per cent of the trees have root systems that do not penetrate more than 10 centimetres below the ground. However, according to the recent studies of Dan Nepstadt and his colleagues, this notion is false.

Their research is a very good example of how little we actually know about the root systems of different trees in different kinds of ecosystems. Everybody had always assumed that rainforest trees have very shallow root systems, but Nepstadt and his colleagues were the first ones to really find out whether this was true or not. They discovered, that the rainforest trees actually had very deep root systems. They dug deeper and deeper, but the roots kept on going down until a depth of 21 metres. They were not very thick—the largest roots remained close to the surface—but there were masses of them: the whole ground seemed to be full of bunches of innumerable thin tree roots. The function of these obviously was to catch the precious nutrients before they were be leached too far down in the soil.

When all these possibilities (some of which will be discussed in a more detailed way in the following chapter) are counted together, it becomes obvious that the chances to store atmospheric carbon dioxide in tree biomass are much more significant than has been acknowledged, so far.

Robert K. Dixon, the director of the US Support for Country Studies to Address Climate Change, has estimated that using sustainable forest and agroforestry management practices on 500–800 million hectares in 12–15 key nations could annually sequester or conserve 0.5–1.5 billion tonnes of terrestrial carbon. According to Dixon, different agroforestry systems can store between 12 and 228 tonnes of carbon per hectare, when the underground carbon is also included in the estimates.



## The Princess Who Became a Mango Tree

The daughter of Surya, the sun god, was the wife of a handsome king. One day, while she was walking in a nearby forest, she was chased by a Rakshasi, or demoness. She fled through the forest, but the Rakshasi drew closer and closer. To escape her pursuer, the girl changed herself into a lotus in a forest pool.

The Rakshasi could not enter the pool, so she kept guard over it instead. The king returned to find his wife missing and, as he loved hear dearly, he got on his horse and set off to find her. One day, as he was passing through the forest, he saw this single beautiful flower growing in the silence of the pool. He wanted to take it with him to his palace, so he waded into the water and plucked it.

The Rakshasi was angered. A single blazing look from her eye and the flower was burnt. The king was alarmed and he threw the ashes by the side of the lake and rode away. The Rakshasi also went away, satisfied that she had destroyed the girl.

From the ashes of the lotus flower grew the mango tree. A few years later, the king, passing through the forest still in search of his wife, saw the ripe fruit and took it back with him to the palace as a novelty to show the courtiers.

But as he passed it to his minister, the fruit fell on the ground. From it emerged the daughter of the sun god, the wife of the king. The royal pair were united and lived happily ever after.

J.D. Unruh and his colleagues have estimated that agroforestry could sequester between eight and 54 billion tonnes of carbon in the total of 1.55 billion hectares of land where agroforestry could potentially be practised in Africa. Above-ground biomass would sequester 3–15 tonnes and soil and root biomass 1.3–6.5 tonnes of carbon per hectare.

These figures may seem impressive, but they are, in reality, extremely careful estimates.

## Carbon Storage Forestry as a Rural Livelihood

In the UNCED conference in 1992 the industrialized countries committed themselves to cutting their carbon dioxide emissions back to the 1990 level before the year 2000. This was a modest step, but it was hoped that it would gradually lead to more meaningful moves towards the same direction.

In the Kyoto meeting, at the end of 1997, the industrialized countries finally promised to reduce their greenhouse gas emissions by five per cent from the 1990 level before the year 2012. This was a far cry from the level IPCC had deemed necessary, but in spite of such reservations, the Kyoto Protocol was hailed as a historical first step towards significant reductions in greenhouse gas emissions.

The convention was somewhat watered down in Bonn, in July 2001. According to decisions made in Bonn, the industrialized countries that ratify the Kyoto Protocol can implement most of the agreed reductions in their greenhouse gas emissions by purchasing carbon dioxide emission quotas from other countries, by financing greenhouse gas cuts in the Third World or the former Soviet Union, or by absorbing carbon dioxide into forests or soils of farmlands.

In reality, the industrialized countries—with the significant exception of the USA which produces one-third of their greenhouse gas emissions—committed themselves to reducing their real greenhouse gas emissions by 1.8 per cent of the 1990 level by the year 2012.

The next steps will be more difficult. In order to achieve the necessary 60–80 per cent reduction in global carbon dioxide emissions, much more needs to be done in the North, and the southern countries must also agree to limit the growth of their emissions.



Some southern countries have contended that the Western countries, with only about 20 per cent of the world's population, are producing 60 per cent of all the greenhouse gas emissions. If the USA is producing, on a per capita basis, roughly 100 times more carbon dioxide than Bangladesh, it can't possibly be fair to ask both countries to cut their emissions by 60 per cent, or 80 per cent.

Many Third World countries would like to appropriate the rights to produce greenhouse gas emissions between the different nations on a per capita basis, so that a country with 100 million people would get 10 times more emission permits than a country with a population of 10 million. If there is an agreement on this, most Third World countries could still continue increasing their greenhouse gas emissions for some time, or alternatively, sell their unused quotas to the industrialized countries. The industrialized countries, on the other hand, would have to make very major cuts in their own emissions, or buy some more emission rights from the Third World countries.

The OECD has estimated that the price of the emission permits might already be somewhere between US$ 100 and US$ 350 per one tonne of carbon, when we would be talking about a cut of 20 per cent in the global emissions. According to the Delhi-based Center for Science and Environment, this might earn at least US$ 100 billion a year in foreign currency for the Third World countries. When the world would move towards a 60 or 80 per cent cut in the emissions, the prices of the emission quotas and the worth of their international trade might multiply.

The question on how the emission rights of different greenhouse gases will be distributed may become one of the most important political struggles for the next 30 or 40 years—a kind of New International Economic Order of the twenty-first century.

Besides emission permits, also the managing of carbon sinks—forests absorbing carbon dioxide from the atmosphere—could become a tradeable commodity. If this happens, and the governments are paid for carbon sequestration, perhaps peasants and village communities could also get their share of the income.

The proposal about including carbon sinks into the climate treaty originally came from the government of Finland. Finland proposed

that increases or decreases in the amount of carbon stored in the forests should also be taken into account in the calculations concerning national greenhouse gas emissions. The principle was included in the text of the original framework of the Convention on Climate Change, which was accepted in New York in May 1992, just before the United Nations Conference on Environment and Development in Rio de Janeiro.

In the climate convention negotiations, many environmentalists were against the inclusion of carbon sinks in the treaty. According to them, the sequestration of carbon in forests can only be a temporary relief from the problem, because there is a clear limit to how much carbon the forests can absorb. When the trees start to die, the carbon is again released into the atmosphere as carbon dioxide. In the long run, the only way to halt the build-up of carbon dioxide in the atmosphere is to limit the use of oil, coal and natural gas. And what if the forests that have been grown to store atmospheric carbon dioxide burn in giant forest fires?

Other environmental organizations, however, emphasized the benefits of including carbon sinks into the convention. They pointed out that the principle would, among other things, provide a strong incentive for governments to protect their remaining natural forest areas. Among the supporters of the idea were most of the indigenous peoples of the Amazonas and the union of the rubber-tappers and nut-collectors of the Brazilian Amazonas (CNS).

The establishment of carbon storage forests doesn't have to be a temporary measure. It is possible to manage the forests so that very high amounts of carbon can be stored in the tree biomass for an indefinite period of time. This can simply be done by lengthening the rotation period used in forestry. Also, there is a surprisingly large number of tree species that can live one or several thousands of years and achieve very big sizes—if left in peace.

Carbon storage forests would most probably be less vulnerable to forest fires than ordinary forests. Younger and smaller trees burn much more easily than older and larger trees, which are often surprisingly resistant to forest fires because of their thick bark. Some trees, like the baobab, cannot burn in any kind of forest fires, as long as they remain alive, because of their high moisture content.



Global warming will definitely increase the number and severity of forest fires in different parts of the world, but the higher the average age of the forests, the less the damage the fires are likely to do. The trees in the ordinary commercial forests are hardly ever grown to an age that would enable them to survive even a relatively mild forest fire.

Many southern organizations have pointed out other dangers. If governments and private companies start to establish huge carbon storage forests in the South, this might lead to large-scale privatization of common lands and to large-scale displacement of many people. When the government of Thailand announced that it was going to establish 4.5 million hectares of eucalyptus plantations, the plan was violently opposed and finally brought down because it would have displaced 5–10 million rural people. For instance, the US Ministry of Energy has proposed the establishment of 700 million hectares of new plantation forests in the Third World, in order to halt global warming. What would be the scale of displacement caused by such unimaginative approaches?

However, there might be ways to modify the idea of carbon storage forests so that it becomes truly useful. The most important thing is to ensure that the arrangements related to carbon sequestration will put more resources into the hands of the poor, instead of further narrowing their already limited resource base.

This can be done in several different ways. Perhaps the best alternative would be to demand that, if there are to be carbon storage forests, only trees producing food for human consumption should be planted in them. Also, the carbon storage forests should be open to the local people, so that they can collect edible fruits, nuts, pods, seeds and mushrooms from them, gather dry branches or cones that have dropped from the trees for fuel, and let their domestic animals graze and browse in the undergrowth, once the trees have attained a size where cattle or goats can no longer harm them. The shells of various nuts, fruits and pods and the spoiled fruits could also be used as raw material for biogas, generator gas, wood chips, brickets, liquefied wood oil, charcoal or hydrogen. The programmes could emphasize the planting of food-producing trees that easily survive bush and forest fires.

We should, perhaps, agree to and support such arrangements, on three important conditions. First, just like in the Bonn agreement, governments should also, in the future, be able to implement only a certain percentage of their emission reductions through joint ventures, by absorbing carbon dioxide into the forests, or through purchasing carbon sinks or additional emission quotas from other countries. It is important that governments have a strong enough incentive to develop energy-saving technologies and renewable energy sources. As the possibilities of absorbing carbon dioxide into forest biomass are limited, some of these possibilities must be reserved for taking a certain amount of the already existing carbon dioxide out from the atmosphere.

Second, carbon sinks should only be included if the income from establishing and maintaining carbon storage forests is divided between the governments and the local people. Third, forests should only be counted as carbon storage forests if they contain food-producing trees and if they are kept open for the local people.

The most important issue is whether the programmes are to be implemented in a way that would appropriate more resources for the poor, or whether they would lead to the further narrowing of the resource base the poor depend on.

There are numerous different food-producing trees that can attain a very large size. Carbon storage forests that would only contain large-sized, food-producing tree species would quickly become very important for the local people. People could collect part of their food from the forests, besides which they could collect nuts, fruits, pods and oilseeds to be sold in order to earn some money. Such forests would be especially valuable for people during wars and famines, because they would be likely to produce large quantities of nutritious food even then.

Trees are not affected by wars in the same way as annual crops are: they will keep on producing food even when people cannot work in the fields. Many trees even produce food during the worst drought years. If suitable mycorrhiza mushrooms are grown into the roots of the trees before planting, the forests would also be likely to produce large amounts of edible mushrooms.



Carbon storage forests consisting of food-producing trees might actually come to be regarded as sacred forests, with the local people doing their utmost to protect them—even risking their lives for them, if the need arose. This is very important from the viewpoint of carbon sequestration. If the establishment of carbon storage forestry means that local people will lose valuable resources, the forest is not likely to remain there for very long. People would be likely to rip off the seedlings from the ground during the night time, or replant them again—upside down. People would not hesitate to cut wood from the forest, whenever they could do this without the danger of being caught. It would be next to impossible to protect very large forest areas from a hostile local population, even if numerous guards were hired. Also, if the guards were only paid small salaries, it would be easy enough to bribe or coerce them. Higher salaries, on the other hand, would make the cost of protecting the forests prohibitively high. During the dry season, only one person hating the carbon storage forest deeply enough could easily burn much of it with a single match, and local people would not be likely to volunteer into the fire-fighting operations.

In practice, the best and, perhaps, the only way to ensure that a carbon storage forest—and the carbon stored in the trees—remains for hundreds of years, is to make it so important for the collective food and economic security of the local people, that it finally becomes some kind of sacred forest.

To make the model interesting for governments as well it could, perhaps, be decided that all the income from selling the carbon sinks, or from the tradeable emission permits created by these carbon sinks, would go to them to finance their public health care, education, social security, employment and environmental programmes. The local people would benefit from the existence of large 'food forests' that they could use freely, as long as they did not touch the larger living trees.

Another interesting possibility would be to concentrate on the household or village level. In this model, village communities or individual households would make carbon sequestration agreements with the government of their country.

This possibility should not be excluded, because billions of people living in Asia, Africa and Latin America will anyway be absorbing a lot of carbon dioxide from the atmosphere by transforming their fields to multi-storey home gardens.

This process is already effectively turning fields and pastures into some kind of 'semi-forest' that can absorb significant quantities of carbon dioxide out of the atmosphere. Also, the transformation of many types of woodlands and open forests into multi-storey home gardens can sometimes increase the amount of biomass per hectare.

The conversion of older forests into tropical home gardens usually leads to a substantial decline in the carbon store, but even here the difference is not as dramatic as when the forest is cleared to become farmland or pasture, in which case the carbon store in the vegetation is usually reduced by 90 or 95 per cent. Also, even in these areas it is possible to develop man-made multi-storey home gardens that will finally contain a larger storage of carbon than the natural forest replaced by them.

There is one more possibility related to trees and carbon sequestration, which has not—to our knowledge—been mentioned in the discussions about the subject.

There is an upper limit for the amount of carbon that can be stored in forests and trees. This is an obvious fact that cannot be denied. However, there is at least one way to overcome this limitation. If we grow wood and carbonate it to charcoal, it becomes entirely resistant to biological degradation. Bacteria and other micro-organisms will no longer be able to digest it. If charcoal is buried in the ground (for instance in old coal mines) the carbon dioxide tied to it will remain in the ground for ever—unless these artificial coal mines are excavated and the charcoal used as fuel.

This could be the only way to safely remove and store very large quantities of carbon dioxide from the atmosphere. In controlled combustion in a metal kiln it is possible to transform approximately 70 per cent of the wood's carbon content to charcoal. Four billion cubic meters of wood would thus be enough to produce approximately 700 million tonnes of charcoal (pure organic carbon).



To absorb all the carbon dioxide emissions that are currently not mopped up by the oceans and by the soil from the atmosphere would require between 500 million and one billion hectares of well-managed forests or tree plantations producing wood for the charcoal. This might not be a very practical proposition, even if the forests and tree plantations would grow tree species that would also produce food, fodder and other necessities for the people.

However, producing and burying charcoal might become an interesting option within a hundred years or so, if we then want to remove some of the extra carbon dioxide from the atmosphere, after having stabilized the situation by a shift to energy systems based on renewable resources.

It is likely that future generations will be very interested indeed in such options. They have very good reason for this. Without large-scale carbon storage forestry programmes and the establishment of 'charcoal mines' the sea level will most probably keep on rising for hundreds or, more likely, thousands of years. This might doom billions of people and their descendants to extreme poverty for hundreds of generations. Such a scenario can only be prevented if some of the extra carbon dioxide is somehow mopped up from our atmosphere.

## A New Scientific Discipline?

The research carried out by forest scientists has, thus far, only aimed at increasing and maximizing the amount of wood produced by the forests. To our knowledge, no research has been done within the framework of how forests should be grown if the main goals were to improve the food security of the poor and maximize the amount of carbon stored in each hectare of forest.

We do not know what the best management practices would be if forests are grown for such purposes. How many seedlings should we start with? What would be the optimal planting density? When should we start thinning the stands? How many trees of a certain species should there be for each hectare, when the forest is 50, 100 and 200 years old? Will the management practices that produce the largest carbon storage result in smaller food production, or can we achieve both the maximum food production and the maximum car-

bon storage at the same time, by growing a relatively small number of very large trees on the same land area? If a compromise has to be made between the two main goals—carbon sequestration and food production—how should we decide? Should the trees be grown from seeds and not from seedlings, in order to ensure that they develop strong and deep root systems?

We do not know what the optimal rotation cycle would be for each species: the older the trees grow, the more carbon they will store, but after a certain age, many species may experience a very serious decline in the amount of food they will continue to produce. We do not know what combinations of trees would be likely to produce the best results, either in terms of tonnes of carbon or in terms of proteins and calories produced for human consumption. We know hardly anything about the root systems of many tree species, and how much carbon could be stored in them, not to say anything about the interactions of the root systems of different tree species. Would a mixture of deep-rooted and shallow-rooted trees produce, in the long run, the largest underground carbon storage?

We will need a tremendous amount of experimentation and research before we know answers to these questions. The matters will be made more complex by the fact that there will be hundreds or thousands of relevant tree species, each of which will be behaving in a somewhat different way. When we consider all the possible combinations of different species, the complexity of the task becomes almost mind-boggling.

We need a new scientific discipline, a branch of forestry science, that would concentrate on such questions. We could call this hypothetical new discipline, 'carbon storage forestry'. However, scientific establishments are not very flexible. There is a tremendous amount of inertia and resistance to even minor changes, built into their long traditions and their power structures, in which the oldest researchers always hold the most important power positions. Therefore, the forest scientists are, at first, not likely to welcome the ideas outlined in this book as something that complements their own research. On the contrary, most of the forest scientists are likely to take our arguments as a criticism of their own work, as a claim that they have been doing their research the wrong way, that



## Why the Ebony Tree Has Dark Wood

When the earth sank beneath the Great Flood, a Kond and his wife decided to seek shelter inside a gourd. They took a bundle of sticks with them so that they would have fire when they came out. They pulled the gourd shut after them and went to sleep.

Many, many days later they awoke. They broke the gourd and saw that the water had dried and a new world awaited them. They emerged from the gourd carrying their bundle of sticks. The Kond lit a fire with the wood and the couple slept. The next morning, the Kond and his wife went to explore this new world. In their absence, a burnt twig took root and grew into an ebony tree, and when they returned they saw it. The tendu is black because it came from a charred piece of wood.

—*Tribal legend of the Konds of Ganjam*

they have missed the important things and have more or less wasted their careers as scientists. It is likely that the new ideas will only be accepted gradually, little by little, and often through the younger generations of researchers.

In order to speed up the process a bit, it is also important that thousands of laymen, 'ordinary people' that are not 'real' (or official) scientists, start to carry out their own research and experimentation in this field. It is very likely that such amateur researchers will become the real pioneers in carbon storage forestry studies, and that the governmental forest research institutes and other official research establishments will follow them somewhat later.

### Trees as a source of fuel and construction materials

There are also a number of other ways through which trees can help us in preventing a potentially disastrous runaway greenhouse effect.

According to the latest estimates, cement production is already responsible for seven per cent of the global carbon dioxide emissions. Cement production produces $CO_2$ emissions in two different ways. The conversion of the raw material (limestone or calcium carbonate) to the final product (cement or calcium oxide) is a chemical reaction in which a lot of carbon dioxide is released. Besides this, a lot of coal is needed in order to heat the kilns to the temperature of 1,450 degrees Celsius, which is necessary for roasting limestone.

The world currently produces 1.4 billion tonnes of cement every year, and the production increases by five per cent annually. The production of cement is increasing very rapidly in many Asian, African and Latin American countries, while growing percentages of their populations are moving from the countryside to the cities. According to John Lanchberry of the Verification Technology Information Centre in London, the cement industry will soon be responsible for about 10 per cent of the global carbon dioxide emissions.

An alternative to these trends would be to increase the use of bamboo, wood and mud—and different composite materials partly based on them—to replace cement in the construction of houses. Gandhiji actively promoted the use of mud and bricks made of mud for such purposes. Houses built of mud are less hot in summer and warmer in winter, which reduces the need for heating and air conditioning. Mud is cheaper than concrete, and mud bricks can be produced without causing carbon dioxide emissions—either by solar energy or by using firewood.



Traditional Indian houses, however, were not made only of mud. They were based on a kind of composite structure that incorporated mud with tree branches and shoots. This kind of structure is surprisingly strong. When the terrible earthquake of 2001 killed tens of thousands of people and destroyed the homes of five million people in Gujarat, in many areas it was only the houses built by these traditional methods that were able to withstand the holocaust. For example, in the village of Ludiya in Kutchch, all the other kinds of buildings collapsed, while every single one of the round traditional houses that had used the mud-wood composite structure remained standing. The round houses that had been built of mud and stones only, and which had thus imitated the mere facade but not the actual structure of the traditional buildings, did break down.

Wood is, at present, a much more expensive building material than mud, at least in India. However, if the forests were managed better, and on a community basis, the production of timber could be increased so much that it would become more widely available even for the poorer households.

It is a widespread prejudice that wood is not suitable for the construction of buildings more than three storeys high, but this is actually not true. The natural strength of wood can be increased by using compressed wooden beams instead of natural logs. Wood can be supplemented with other materials like stone, iron, bricks—or cement—but a major part of even the somewhat higher buildings can be made of wood.

Wooden houses need not be more fire-prone either. Compressed wooden beams do not catch fire easily, and the safety of the buildings can be further improved by the use of some gypsum plate (plasterboards) in the walls and roofs. Actually, the number one fire hazard in all types of buildings consists of various plastic materials in the furniture, clothing and other household equipment. Such materials often produce very toxic fumes that can also become dan-

## The Monkey's Heart

On the banks of the Yamuna river grew a jamun tree. A monkey family made this tree their home. The monkey husband was a friendly fellow. He loved the purple jamun fruit and ate greedily of it, but he was willing to share it, too.

Across the banks of the river lived a crocodile family. The male crocodile swam across to the bank of the jamun tree every day to sun himself. The monkey and the crocodile became good friends and the crocodile ate jamuns given to him by the monkey.

One day the monkey, seeing the enjoyment of the crocodile when he clamped his jaws on the fruit, said: 'Crocodile, my friend, why don't you take some fruit home for your wife today.'

'What a good idea,' said the crocodile. The monkey collected some fruit and when the evening darkness deepened, the crocodile swam back to his home.

His wife ate the fruit. Her eyes narrowed into slits with enjoyment and her jaws yawned with pleasure. 'My husband,' she said, 'where did you get this tender, sweet fruit?' The crocodile told her about the monkey that lived on the tree and distributed the fruit.

The crocodile's wife grew silent as she thought. Saliva dripped from the corners of her mouth. 'If these jamuns are so sweet,' she mused, 'how much sweeter would be the heart of one who lives on them.' She ordered her husband: 'Bring me the monkey tomorrow. I will eat his heart.' The crocodile was horrified. He tried to remonstrate with his wife but she was adamant.

The next day, a tense crocodile came to the bank of the jamun tree. 'My wife thanks you for the delicious fruit.' His eyes avoided the monkey's as he spoke. 'She would like to repay your hospitality by inviting you to dinner.'

The monkey did not see anything strange in his friend's behaviour. 'Certainly,' he said. 'Let's go. It will make a change from the jamun fruit.' He sat on the crocodile's back and the latter pushed himself sluggishly into the water.

The journey was a silent one. Half-way through the monkey looked down and saw the crocodile crying, tears streaming out to join the water of the river. 'What is it, my friend, what makes you so sad?' he asked, concerned.

The crocodile replied: 'Forgive me, monkey. I have tricked you. My wife is not going to feed you. She desires to eat your heart for she says that it must be as sweet as the jamun fruit you eat. And I am too scared of her not to bring you. Forgive me.'

The monkey gave a little jump of alarm. First he thought that he would plead with the crocodile but saw that that would be of no use. So he thought quickly and said, 'Oh, my, is that all? There is no need to be unhappy, crocodile. I will happily give my heart to your wife. What need have monkeys for hearts?'

'But,' the monkey continued blithely, 'unfortunately today is the day that I wash my heart. Early this morning I soaked it in the river and hung it out to dry on the branches of the jamun tree. Let us go back and collect it.'

Crocodiles are not known for their intelligence. And this one's grief clouded his common sense even more. 'Very well,' said the crocodile, relieved that his friend had taken the news so well. He turned around and the pair headed back to the banks of the tree. As soon



as they neared the tree, before the crocodile could see that there was no heart drying on its limbs, the monkey leapt up and caught a branch.

From that day on, the monkey refused to come down from the jamun tree. But, because he was a generous soul, he threw the fruit down to the crocodile who sunned himself on the banks of the river.

gerously ignited in the air. Because of the extensive use of plastics, such dangerous fires can take place in all kinds of buildings, not depending on the mixture of the materials used in the main structures.

On the western coast of the USA and Canada, about 90 per cent of all buildings that have from three to five storeys are made of wood. Similarly, a great majority of all new houses in other parts of the world could also, at least in theory, be constructed of wood. However, the more densely people want to live, the more cement will obviously be needed in the construction of skyscrapers or very high blocks of flats. In any case, it would be a good idea to replace as much cement as possible by wood. This could, in the future, transform the construction industry from a very significant source of carbon dioxide emissions to a major carbon sink: the carbon stored in the buildings would be likely to remain out of the atmosphere for decades, if not centuries.

Needless to say, the annual replacement of 1.4 billion tonnes of cement by mud and timber would be a major project which would require very large forest areas. However, these forests could also produce fodder, firewood and small timber for the local people. If suitable species were to be favored, they could also produce huge quantities of food for human consumption. There are hundreds of different tree species that can produce both nutritious food and high-quality timber. A few notable examples are: sal (*Shorea robusta*), walnuts (*Juglans* spp), mangoes (*Mangifera* spp), oaks (*Quercus* spp), beeches (*Fagus* spp), chestnuts (*Castanea* spp), ebonies (*Diospyros* spp), the brazil nut (*Bertholletia excelsa*), meru oaks (*Vitex* spp), many pine species (*Pinus* spp), several araucarias (*Araucaria* spp), and so on.

The growing of tree crops can also reduce greenhouse gas emissions from conventional agriculture. The extremely energy-intensive model of agriculture in the USA annually consumes about 1,400 litres of oil-equivalents of fossil fuel energy for every man, woman and child living in the United States of America. Most of this is used in the production of fertilizers. The massive overuse of fertilizers also causes significant emissions of another important greenhouse gas, nitrous oxide.



Trees do not require as much fertilizing as annual crops. Also, trees are usually fertilized with organic fertilizers, which do not consume fossil fuels. In any case, they can utilize the nutrients that are added into the soil much more effectively than annual crops. Leguminous trees and some other tree species can fix nitrogen in the soil with the help of the bacteria growing in their root systems. They do not need any nitrogen fertilizers, and their litter can also provide sufficient nitrogen fertilizer for any adjoining crops that do not have the similar nitrogen-fixing capacity. All kinds of trees can also act as nutrient pumps that bring up nutrients from the deeper soil layers and recycle them into the ground in their litter.

Because of the large size of the trees, tree-based agricultural systems are more difficult to mechanize. This reduces the greenhouse gas emissions in two ways. First, if more human labour and fewer machines are used, less oil will be consumed. Second, without tractors and other heavy machinery there will be less tilling, which reduces the decomposition of humus and thus the carbon dioxide emissions from the soil.

# 3

# Growing Food-Bearing Trees

THE BREEDING OF food-producing trees has received much less attention and resources than the breeding of annual plants.

There are several reasons for this. One of them is that most of the technical know-how about tree breeding is in the hands of forest scientists, who tend to be interested only in species that produce valuable timber or wood for pulp mills. Agricultural scientists are not so familiar with trees. Instead, they like to concentrate on annual plants. Horticulture and pomology have always been slightly marginal areas of scientific research, dropping between the major streams of research activity.

Another obvious reason is that the breeding of food-producing trees requires more time than the breeding of annual plants. Even with annual plants, it typically takes about 20 years to breed a new, stable variety. Although many tropical trees start flowering during their first year of growth, most species require several years or even decades before they start to flower and produce seeds. This means that food-tree breeding can be hopelessly slow from the viewpoint of a human being. Our time on earth is very limited indeed.





According to Dianne Rocheleau and John Raintree:

> The potential benefits of a systematic effort to select and develop improved agroforestry germplasm can hardly be overdramatized. Agroforestry is, so to speak, in the Stone Age in this regard. To make the analogy more precise, the current situation in agroforestry is analogous to the early Neolithic, when man first embarked on the road of agricultural domestication. In selecting woody components for agroforestry systems, agroforestry designers today are faced with essentially wild plants analogous to the early ancestors of maize, wheat, rice and all our other highly domesticated crops. The genetic heterogeneity of tree germplasm and, hence, its potential for selection and improvement is a fact that is repeatedly emphasized in international meetings on the subject. In the few instances that tree and shrub germplasm (mainly the commercial plantation crops like oil palm, rubber, tea and coffee) have received the kind of attention we take for granted in field crops, spectacular improvements have resulted.

To take only a few examples, the average hectare yield of rubber plantations has increased seventeen fold during this century, due to breeding efforts and better management. A hectare of wild seabuckthorn forests produces only a few hundred kilograms of berries in a year, but selected cultivars can yield 15–20 tonnes per hectare.

Rocheleau and Raintree exaggerate the situation a little bit, because there are a number of food-producing trees which have received quite a lot of attention from plant breeders. Such trees include for example, citrus fruits, the domesticated apples, kiwi fruit, oil palms, bananas, mangoes, guavas and many others. Besides this, farmers have done some selection on numerous other fruit tree species that have been cultivated for a longer time, and bred thousands of different varieties of these.

However, none of these fruit and nut trees has been improved even nearly as much as all our main annual food plants. Most of the widely or relatively widely cultivated food-producing trees have never been subjected to systematic selective breeding. And there is a surprising number of extremely interesting and important food-producing tree species that have not even been domesticated yet, let alone actually bred.

It is tempting to imagine what could be achieved through the selective breeding of tropical trees producing edible pods, or trees like marula and mongongo.

At the moment, two very different systems of plant breeding coexist in the world: the traditional system that has existed for 12,000 or 15,000 years, and the modern or scientific (or western) plant-breeding system, that has existed for less than 100 years. The traditional system used to breed hundreds of thousands of different local varieties. The modern system is producing a very small number of highly productive varieties, that are now being spread by commercial companies and by governmental and non-governmental extension services on a very large scale. In other words, a very small number of modern varieties is replacing a huge number of traditional varieties, plus the whole traditional plant-breeding system. This applies both to annual plants and, to a lesser extent, to food-producing trees.

The purpose of this chapter is to propose just the opposite: the partial replacement of the modern tree-breeding system by an improved version of the traditional system. The method proposed could be called either 'improved traditional', 'scientific traditional' or 'high yield-maximum diversity' tree-breeding system.

The logic of the breeding efforts has been somewhat different for annual plants and food-producing trees, so we should perhaps start this account by analyzing the process from a historical perspective.

## A Brief History of Agriculture and Plant Breeding

Human beings started to domesticate and cultivate different food-producing plants at least 12,000, and perhaps even 15,000 years ago. Before this, humans had only eaten plants that grew in the wild. Now they started to transfer wild plants nearer to their homes and to sow and grow more plants from the seeds they produced. This process, the beginning of the domestication of food-producing plants, has often been called the neolithic revolution.

When people started to domesticate various food plants, they also became plant breeders. When they sowed seed into their fields, the outcome was a great variety of plants, the individual characteristics of which varied to a great extent. Some contained large and palatable, others very small and hardly edible seeds.



When people stored seeds for the next growing season, they took them from the plants that had produced the best food or the largest crop. This meant that they started to carry out selective breeding of the plants they were growing. However, the breeding efforts of our ancestors only proceeded at an agonizingly slow speed. They were hampered by a number of serious obstacles.

One was the lack of good breeding material. Some of the most useful and desired characteristics may have been very rare. It could be that there was only one plant in a million, or only one tree in an area covering 100,000 square kilometres, that harboured the genes that produce a certain valuable characteristic in an annual plant or in a tree.

The mobility of the early agriculturalists was not high—most of them probably spent their whole lifetime within 30 or 40 kilometres from the place they were born in. There were no practical means for exchanging valuable genetic material with other farmers living hundreds or thousands of kilometres away.

Today, plant breeders can choose their material from vast selections, many of which already are the result of prolonged domestication and selection processes. Our plant-breeding ancestors did not have such options.

Another factor that slowed down the process even more was the lack of knowledge on how the genes, or the hereditary mechanism, actually works. Even when people took the seeds from a plant or a tree that had all the desired characteristics, the plants that grew from the seed did not necessarily contain the same valuable qualities.

Both the mother and the father contribute a factor equally, a gene or several genes, that govern the quality of a particular trait in a plant or a tree. The characteristics that are visible in the offspring are always a mixture of the characteristics of both the mother and the father plant.

Matters are further complicated by the fact that some of the genes influencing a certain trait are dominant and some are recessive. In a plant that has got a recessive gene from the father tree and

a dominant gene from the mother tree, only the characteristic caused by the dominant gene becomes visible. However, in a plant that has two recessive genes, the recessive genes control the development and the characteristics of the plant.

When both the mother and the father plant display a desired characteristic, it may be caused by two recessive, one dominant and one recessive or two dominant genes. If both parent plants contain one recessive gene causing an undesired characteristic, and one dominant gene causing a desired characteristic, the undesired trait will be visible in 25 per cent of their first-generation (F1) offspring. If only one parent has the undesired, recessive gene, it will not be visible in the first generation, but can re-appear in the second. If both parents have two recessive or two dominant genes causing the desired characteristic, their offspring form a 'stable variety' in terms of this quality. They will always 'breed true' and the desired characteristic will always be present in their offspring, generation after generation, as long as they only breed with each other.

If you know these basic laws of genetics, which were first discovered in 1857 by Gregor Mendel, a monk who was also an amateur botanist, selective plant and tree breeding becomes simpler—at least if you are only interested in one characteristic, like the sweetness or sourness of the fruit. Sometimes this is enough. For instance, wild marula trees always produce very large amounts of fruit, so it is not so important to emphasize the size of the fruit crop. The single most important characteristic is the size of the fruit, so it makes sense to concentrate on this. Also, all wild rowan-trees produce a lot of berries if the environmental factors are favorable. The most important problem is the sourness of the berries, so it would make sense to concentrate on breeding trees that produce sweet berries.

However, it is often important to include more than one characteristic in the breeding programme. This makes things a bit more complicated. Genes related to certain characteristics may sometimes be situated so close to each other that they cannot be separated and are always inherited together. In such cases, it may be impossible to separate a gene producing an undesired characteristic from another gene producing another, desired characteristic. Moreover, many characteristics are produced by more than one gene.



## Bhima's Trial of Strength

Mahaprabhu made men, animals and trees. Men increased in number and strength and started making villages. To maintain order, Mahaprabhu made Chalika the king of men, and Chalika made a government to help him rule. Mahaprabhu made a chief and watchman for every village. Then the animals increased. Mahaprabhu made a king and watchmen for them too. One day, the trees assembled on Hemagiri mountain and complained, 'You have made a government for all but us. We have no one to defend us, no one to protect us.'

Bhima was passing by. 'Why are all the trees together?' he asked himself. He hurried to the top of Hemagiri mountain and asked the trees why they had assembled. They told him their problem. 'I will see who the strongest is,' decided Bhima. He pushed each tree, and each tree fell over except the tamarind, the pipal and the banyan. Bhima told Mahaprabhu about the test he had taken.

Mahaprabhu came down to Hemagiri mountain. He made the tamarind the king. The banyan, which spread its branches everywhere and so could get more information from around earth, he made the minister. And he made the pipal the watchman. 'Whenever the wind blows or a storm approaches, you will warn the other trees.'

And that is why the leaves of the pipal rustle in the wind.

*—A Muria tribal legend*

So things may be a bit complex, even if you understand how the hereditary mechanism works. However, without this knowledge, progress must remain frustratingly slow.

It was impossible for our ancestors to identify the father trees that had fertilized a certain fruit of a certain tree. So the trees and plants they grew from the seed of a superior mother tree, typically contained a very mixed lot of different characteristics. Also, because they did not understand how the hereditary mechanism actually worked, they could not weed out the undesired traits hiding inside the recessive genes. They kept on popping up, generation after generation, even though the farmers eliminated all the plants that visibly contained these harmful characteristics.

Within this framework, there was a big difference between annual plants and trees. Annual plants were sown every year, and in very large numbers. There can be hundreds of thousands of annual plants in one hectare! When the selection processes were continued year after year for thousands and thousands of plant generations, the process gradually led to the elimination of the most undesired characteristics. In practice, farmers had bred millions of different local varieties or cultivars of various annual food plants. These were stable varieties that bred true: they could be sown and planted generation after generation with good results, because the 'bad genes' had been eliminated during a prolonged domestication and breeding process.

With trees, the process became very different, for obvious reasons. The temporal gap between generations is longer with trees. Some tropical trees, like the algarobas for instance, often flower when they are only one year old. However, other species require 10, 15, 20, 50 or 100 years to reach full maturity. Moreover, the theoretical gap between two generations is very different from the practical reality here, because our ancestors most probably did not carry out any systematic tree-breeding programmes. An annual plant must be sown again each year, but a fruit tree is usually left standing for decades or, in many cases, for hundreds of years. Baobabs and chestnuts can continue producing fruit crops for thousands of years. This means that the real average distance in time between two generations of trees can often be very long indeed.



Our ancestors probably did some selection before they transplanted seedlings or germinated seeds in order to grow fruit trees on their homesteads. This is most probably true of at least the species that people could propagate vegetatively from cuttings or from root suckers, like guavas, breadfruits and figs.

After this, the breeding process became much slower, but it did not stop. Trees that were planted on homesteads sometimes produced seedlings that grew to become far superior to their parents. People preferred such trees and let them grow on their land. If a tree produced sour fruits or very small fruit, people cut it down and planted other trees to replace it. When the remaining, more productive trees fertilized each other and new trees happened to grow from their seed, they often produced even better fruit crops than either of the parent trees.

Within millennia this resulted, in the case of some widely cultivated tree species, in the selection of high-yielding strains that could be called stable varieties. For example, domestic apples cultivated in Finland can no longer produce offspring that produce very small, berry-like fruits, unless they are hybridized with wild apple trees. The genes that produced berry-like fruit were eliminated from their genetic base a long time ago. Similarly, the fruits produced by mango trees in Africa can differ in size and fibre content, but all of them produce fruit suited for human consumption.

The vegetative propagation of the best specimens from cuttings (or by grafting, budding or layering) accelerated the process. Most of the trees growing in many gardens and homesteads started to be vegetatively propagated clones of various superior specimens. The introduction of fruit trees to new faraway geographical regions probably had a somewhat similar effect, because people tended to take with them seeds, cuttings or grafts from the best trees of the domesticated or semi-domesticated strains.

Since then, the modern plant-breeding technologies have vastly accelerated the breeding process. New cultivars and extensive use of chemical fertilizers and irrigation have produced large increases in hectare yields. However, at the same time our food-production systems have become much more vulnerable.

There are between 250,000 and 300,000 plant species in the world. Of these, 10,000–50,000 are edible in their wild forms, and most of the others could be made edible through selective breeding. Formerly, people used to utilize a very wide variety of edible plants as food. Indigenous peoples of North America—an area relatively poor in biological diversity—utilized at least 1,112 different plants for food. Nowadays, only 150–200 plant species are widely used as food, and 60 per cent of the calories and protein consumed by humans come from three species: rice, maize and wheat. Moreover, the genetic basis of the widely cultivated food plants has become frighteningly narrow.

According to one estimate, there used to be something like 500,000 different varieties of rice in South Asia alone, but most of them have already been wiped out by a small number of new, high-response rice cultivars. In the Philippines, Indonesia and Vietnam, a single rice variety, IR-36, constituted 60 per cent of all rice production in 1982. In Egypt, a country that had grown onions for at least 7,000 years, only one variety of winter onion, Giza-6 Improved, remained. More than 70 per cent of the genetic diversity of wheat in Saudi Arabia and Lebanon was destroyed within a short period of time by the introduction of a handful of new varieties. About two per cent, or one in 50, of the remaining varieties of our important food plants are now lost in one year.

This frighteningly rapid destruction of the genetic basis of our main food crops is a very serious issue. In traditional farming systems, people usually cultivated dozens of different plants in the same patch of land. This reduced, to a great extent, crop losses caused by insects and plant diseases: because the fields grew a rich mixture of different plants, it was more difficult for the diseases and pests to spread. Also, while one plant belonging to a certain species was not resistant to a certain disease or pest, the next individual perhaps was, because the genetic basis of the crops was not very uniform. The great diversity of different plants harboured large numbers of spiders and ants and other natural predators of the pests, which also helped in keeping their populations in check.

Modern monocultures are in direct contrast to this philosophy. They often grow only one genetically uniform variety of a single species at a time. Fields of this kind can, at their worst, become fast super-highways through which various plant diseases and pests can spread with astonishing speed, destroying whole crops while they proceed.



One of the most dramatic examples of what can happen was the Irish Potato Famine in the 1840s. Practically all the potatoes grown in Ireland at that time belonged to a few cultivars, none of which was resistant to a fungus called potato blight. When potato blight hit Ireland, the whole crop was destroyed. One million people died in the famine and two million more had to migrate to America. The population of the island was cut from six million to about three million in only a few years.

What if something similar were to happen to the most widely spread rice cultivars that have replaced tens or hundreds of thousands of local varieties during the last so many decades? As Richard Douthwaite has observed:

> ...very few people also know that the (food) system is genetically unsustainable and might suddenly collapse, causing the deaths of hundreds of millions of people from starvation and leading to political, social and military consequences comparable to those of a nuclear war.

In a monoculture, damages caused by pests and plant diseases are fought by two different methods. First, whenever a new disease or pest becomes a truly major problem, plant breeders try to breed new varieties that are resistant to the disease or pest in question. However, this takes so much time that often a lot of damage is done before the new resistant varieties are available. Also, the resistant plant varieties are usually not resistant for very long. Plant diseases and pests evolve and mutate all the time, and because their breeding populations are very large and genetically diversified, it will not usually take long before they have overcome the problem. In other words: the resistance bred into cultivated plants is not permanent, but has to be replenished and renewed over and over again with new genes.

As Dr J.P. Kendrick from the University of California puts it:

> If we had only to rely on the genetic resources now available in the United States for the genes and gene recombinants needed to minimize genetic vulnerability of all crops into the future, we

would soon experience losses equal to or greater than those caused by the southern corn leaf blight several years ago—at a rapidly accelerating rate across the entire crop spectrum.

The problem is, that when the genetic basis of the cultivated plants becomes more narrow, plant breeders will have less and less material that they can use in order to renew the resistance of these plants against plant diseases and against the at least 15,000 known species of pests.

The other way to limit the damage is the use of pesticides and fungicides. This has proved to be a very problematic approach. Pesticides also kill the natural enemies of the pests, and sometimes the populations of these natural enemies recover much more slowly than those of the targeted pests. Field trials have shown that wrongly timed and measured applications of pesticides can actually increase pest populations by 1,250 times.

Extensive use of insecticides has led to the resurgence of several insect pests of rice that were of only minor importance before. One of them is the brown plant-hopper, which became Asia's most damaging rice pest in the 1980s, and started to consume rice crops in South and Southeast Asia at an unprecedented rate.

In the USA, it has been estimated that crop losses due to pests would increase from 33 to 42 per cent, if the use of pesticides were to be eliminated. It is interesting to note that the Americans currently lose, in spite of extremely heavy use of pesticides and other agricultural chemicals, one-third of their crops to pests. It would be interesting to compare these figures to the losses suffered by the traditional farming systems that do not use any pesticides or fungicides, but which cultivate dozens of different plants and trees in the same land area. They have probably suffered much smaller losses.

Strawberries are supposed to be prone to pests and diseases, but one of the writers of this book (Risto Isomäki) has suffered practically no such losses in a strawberry field that has imitated the traditional farming systems. Individual strawberry plants have been separated from each other by other plants, and there has been a conscious effort to increase the spider and ant populations by bringing decaying pieces of wood into the garden.



## The Sorrow Remover

Duli Chand, a nobleman of the town of Patti, had four married daughters and one unmarried one. For years he and his wife had prayed for a son, and he had grown embittered with God for not giving him one.

One day, the five sisters went on a picnic and they saw some *sadhus* singing devotional songs. The youngest sister was so moved that she removed her jewellery and distributed it among the *sadhus*.

When the sisters came home, Duli Chand saw the bare arms and neck of his youngest daughter and was told that she had given away her jewels to men of God. Infuriated, the father summoned all five daughters and asked, 'Who cherishes and protects you? Who gives you food, clothes and jewellery?' The four elder sisters answered promptly. 'You, Father.' But the youngest looked at the sky and said: 'God is my protector.'

Duli Chand's anger increased. He found a deformed leper and married the youngest, Bibi Rajani, to him. 'I will see how God protects you now,' he said and threw the couple out of his house.

Bibi Rajani went from village to village begging for food for her husband and herself. She took her husband to each temple on pilgrimage. While on their travels, they came to Amritsar. Bibi Rajani made her husband comfortable under a ber tree on the bank of a water-hole and then went away to beg for the day's food.

The leper sat under the tree and watched the pool of water. He saw the miracle of jet black crows diving into the water to cool off and emerging a glistening white. He dragged himself to the edge of the water and timidly dipped his body in. With his little finger, he held on to a branch of the ber tree. He was cured immediately, his body coming out whole from the pool.

When his wife returned, she did not recognize her husband. She refused to believe that the healthy stranger standing in front of her was a leper that had been cured by the miracle water. Both of them went before the Sikh Guru, Ramdass.

Guru Ramdass took them to the pool. There he showed Bibi Rajani her husband's leprous little finger which had held on to the ber tree. He dipped the finger in the pool and it came out whole.

A tank was built around this pool and it has, till today, the reputation of miraculous healing. The ber tree on its bank is the 'Dukhbhanjani Beri'.

*—A legend from Punjab*

Still another problem is the development of resistance to chemicals. The pests, viruses and fungi have an ability to adapt to changing environmental conditions—which includes human-made poisons. When some individuals in a pest population find a way to survive a pesticide, all further spraying favours the individuals with the genetic or behavioural characteristics which allow them to survive the chemical. Because the pesticide will kill most other insects, the resistant pest population soon starts to dominate the area.

The chemical industry has tried to develop new pesticides in order to replace the older ones which have become almost useless in many areas. So far, the pests have been able to develop new resistant strains much more quickly than the scientists have been able to create new poisons. According to Dr Sawicki of the Rothamstead Experimental Station:

> Established resistance can be dealt with only by switching to alternative pesticides to which there is no resistance. This, however, is a transient solution because with time resistance develops to the alternative, which must be replaced by yet another compound. Each new insecticide selects in turn one or more mechanisms of resistance, and each mechanism usually confers resistance to several insecticides.

In practice, this means that our ability to control insect pests is seriously threatened, and the agricultural systems based on monocultures and on the heavy use of pesticides are probably nearing their end.

The development of resistance has often forced farmers to use very heavy doses of several different pesticides. According to the latest estimate, up to 300,000 people may annually die of pesticide poisoning. Pesticides kill bees and other insects that have a great value as pollinators of fruit trees and of many other important crops. If there are too few pollinators, the yield of insect-pollinated crops is reduced.

In many countries, fish and shrimp harvested from the rice paddies have been an important source of animal protein for the people. In Indonesia, for example, fish farming in rice fields used to produce about a quarter of all fresh, closed-water output of fish. In 1969, about 600,000 tonnes of fish were harvested from three million hectares of rice fields. However, the use of chlorinated hydrocarbons and other pesticides practically eliminated fish and shrimp from large rice field areas, or made them too poisonous for human consumption.



Resistant strains have made many insecticides almost useless for malaria control purposes as well. Before the Second World War malaria annually killed three to five million people, in a world that was only inhabited by two billion people, one-third of our present population. Widespread malaria control programmes that followed decolonization reduced the annual mortality to about half a million a year. However, malaria is now making a great comeback. The annual mortality caused by malaria has again reached to two or three million. According to some experts it might climb to 10 million by 2010.

One of the main reasons for these set-backs has been the extensive use of pesticides in agriculture, which has produced numerous resistant strains among the mosquitoes that carry the malaria parasites. According to David Bull:

> Although the use of pesticides in the malaria control programmes itself exerts some selection pressure on the mosquitoes, this is not great. Because vector control programmes are sprayed inside houses, they affect only a small proportion of the mosquito population, and only adults. More and more evidence is accumulating from around the world that it is the use of pesticides in agriculture which exerts the most dramatic selection pressure on the mosquitoes. More pesticides are used in agriculture than for vector control. This agricultural pesticide use affects a greater proportion of the mosquito population and exposes the mosquitoes to pesticides at the susceptible larval stage. This leads to the more rapid development of resistance and the consequent resurgence of malaria.

Also, most of the widely cultivated fruit and nut trees have a narrow genetic base that makes them vulnerable to attacks by fungal or viral diseases or pests. The logic of the situation, however, is somewhat different with with annual plants. Fruit trees do not have a narrow genetic base because too much breeding has been done on them. On the contrary, most of our fruit and nut tree species have never been improved by systematic breeding efforts, besides the original selection done by the farmers that domesticated them.

Ironically, many fruit tree species have a narrow genetic base because no stable varieties have been bred. In the breeding of annual plants, the goal has been, if we exclude some of the breeding efforts with purely commercial motives, to breed stable varieties that will always breed true and produce good results generation after generation (because the undesired characteristics have been eliminated during the breeding process).

It takes a very long time to breed stable food tree varieties. Therefore, horticulturalists have usually taken a kind of shortcut. Instead of continuing the breeding efforts in order to eliminate the undesired characteristics, they have just started to propagate the best individual specimens vegetatively, and produced numerous genetically identical copies of the same tree.

With annual plants, a variety or a cultivar refers to a strain or to a large group of individuals that share a number of similar, desired characteristics. Even if there may be a lot of genetic uniformity in them, the individuals are not clones of the same plant, and each of them is genetically different.

When it comes to fruit and nut trees, a 'cultivar' or a 'variety' refers to a single individual that has just been cloned, or propagated asexually, over and over again. This means that if you have a apple or an orange tree orchard that only grows one variety of apple or orange, your orchard is genetically as uniform as you can get. Genetically speaking, you are only growing several identical copies of the same tree. Therefore, by doing more breeding on our food trees we could, paradoxically, increase and not decrease the genetic diversity of our fruit gardens or orchards.

## Traditional and Modern Fruit-Tree Growing Systems

The modern food-tree breeding system is an integral part of the modern fruit-growing system. Both the modern fruit-tree breeding and the actual cultivation of the trees operate within the same logical framework.

In India, mango is currently cultivated in two very different ways. In the traditional system, there are usually between 150 and 200 relatively large trees per hectare. According to S. Mohammed and L.A. Wilson, the annual productivity of this kind of traditional



system is rather low, ranging from 15 to 25 tonnes per hectare. The production costs in the traditional system are also higher: the trees are so large that the harvesting is difficult. For this reason, a lot of human labour is needed. The establishment costs, however, are minor, and no expensive machinery is needed.

In the modern system a much larger number of trees, between 500 and 1600, are grown on each hectare. The trees are practically always vegetatively propagated—for example, by grafting or budding. In other words, they are exact copies of superior genotypes, that are able to produce very high crop yields per tree. This approach brings a number of advantages.

First, because all trees are identical copies of a high-yielding specimen, every tree growing in the orchard will produce a good crop of fruit. This can result in very high hectare yields in the well-managed orchards. The average annual productivity is higher than in the traditionally managed orchards, varying between 30 and 50 tonnes of fruit per hectare.

Second, the quality, taste and size of the fruits is more or less uniform, which is desirable from a commercial viewpoint. Third, the grafted trees become productive much faster than the seed-grown trees: the farmers don't have to wait for five, 10 or 15 years before the trees start to yield fruit. Moreover, the system requires much less labour. On the other hand, the establishment cost is high, and a lot of capital is required for the machines and for different agricultural chemicals to control the growth, flowering and fruiting of the trees.

The analysis of Mohammed and Wilson is valuable, because it gives us a clear view of the presently existing production systems. However, there might be other options as well.

In the sub-humid and semi-arid parts of Africa, rural people often prefer to grow their mango trees from seed, instead of planting grafted seedlings. The rationale behind this practice is obvious: people know that the seed-grown trees usually survive even during the drought years which kill many, if not most, of the grafted mango trees. This observation seems to be common knowledge in many parts of Africa. The most probable explanation is, that the trees grown from seed grow deeper and stronger root systems, which help them survive severe drought.

One of the authors of this book (Risto Isomäki) has an apple orchard in Southern Finland. The orchard suffers from the attacks of rodents and deer, and of drought in the summer. In such conditions, seed-grown apple trees tend to do better and produce larger yields of fruit than the grafted trees.

Seed-grown mango trees can be huge compared to the dwarf trees grown on modern plantations. They can be more than 40 metres tall and up to three metres in diameter. Obviously, there can only be a maximum of a few dozen mango trees of this size on one hectare. However, a single giant like this has been recorded to produce more than 10,000 fruits, the average weight of each fruit being about half a kilogram, in one fruiting season.

There is a large, seed-grown marula (*Sclerocarya caffra*) tree in Namibia that has been reported to produce, on average, 4.5 tonnes of fruit in a year. In some years, the fruit crop has amounted to seven or eight tonnes. Individual seed-grown guava trees (*Psidium guavaja*) can produce up to 2,000 kilograms of fruit in a season. This is still more impressive, keeping in mind the relatively modest size of even the largest guava trees.

The catch is that only some of the giants produce fruit in such enormous quantities. Many of the older trees do not produce good fruit crops. Also, the quality of the fruits is variable. Most mangoes growing in the African countryside are not of a very good quality. Many have an unpleasantly high fibre content.

Most of the larger trees now growing in the fields have probably not been planted but grown from a seed by accident. Also, when the people have grown the trees deliberately from a seed, it has been difficult or impossible for them to acquire seed that would definitely produce good-quality, high-yielding fruit trees.

However, there might be a way to develop a food-tree breeding and cultivation system that would combine the best aspects of the traditional and modern systems.

We could produce vegetatively propagated clones of the individuals that grow to a large size and that produce exceptionally large crops of good-quality fruits. For example, scions taken from such trees could be grafted onto suitable rootstocks on small plantations, the aim being to produce good-quality mango seed. The seed pro-



## The Devotee's Dream

In Baravala, Gujarat, there is a small shrine of Bhimnatha Mahadeva. It nestles in the shade of a huge sal tree. A devotee worshipped there every day and prayed to become rich. His wish was granted and, through a series of miraculous happenings, he became extremely wealthy.

The devotee was joyous. He wanted to show his gratitude to Bhimanatha Mahadeva. 'What a small, ugly shrine such a powerful god has,' he thought. 'The least I can do is to make a grand temple of brick and stone and paint it so that everyone can see his glory.' He called the temple builders and they told him that they would have to cut down the sal tree to build the temple in its full glory. 'Yes, yes, cut it down,' said the rich man impatiently. 'We must have the temple soon.'

So the masons and the labourers and the artisans got ready and a woodsman was called the next day to chop down the tree. But the rich man tossed restlessly on his bed that night. Bhimnatha Mahadeva appeared to him in a dream and his face was stern. 'What need have I,' he thundered, 'to sit in your closed airless temples? I am the spirit of this tree. It is my home and the home of many gods who live here with me. Will you cut it down to honour me foolishly? Is that how you repay me for making you rich?.' 'No, my Lord,' cringed the rich man. 'I am sorry. I did not know.'

The temple building was called off. The small shrine stands under the sal till today, and after the devotees worship Bhimnatha Mahadeva, they offer flowers to the sal tree too.

*—Folk tale from Gujarat*

duced by crossing two high-yielding mango trees should give good results. As mentioned before, the characteristics that will be visible in the first generation offspring will mostly be a mixture of the characteristics that are visible in either one of the parent trees. Some of the new seed-grown trees might inherit an unfavourable combination of recessive genes and produce small fruit or inferior crops. But this should not be a major obstacle: it is so much easier and cheaper to propagate trees from seed, that it should not be a problem to grow a few extra trees and then remove the ones that perform badly.

Some of the trees grown from seed would produce even better fruit or larger crops than either of the parent plants. The very best trees could again be used as second-generation mother plants in new seed orchards.

The production of high-quality seed might be an excellent way to improve the productivity of the traditional fruit-tree growing systems. If it would be possible to grow, for example, 50 very large but high-yielding, seed-grown trees on one hectare, the annual hectare production might become higher than that of the modern system based on a large number of small trees.

If the advantage of better genetic stock is eliminated by producing the seed in the described way, the larger trees should be able to produce larger fruit crops. The larger trees have more space for their foliage, which they can use to collect sunlight. Also, the deeper and larger the root systems they grow, the more effectively can they utilize the moisture and nutrients in the deeper soil layers. Deeper root systems reduce the trees' dependence on annual rainfall.

The comparative advantages of the systems based on seed-grown trees are likely to be greater, the harsher the conditions.. Seed-grown trees should do better on poor soils, drylands, rocky hill slopes and rainforest lands, or in areas where there is a lot of competition with other vegetation or problems with browsing by large domestic or wild animals. In the first section of this book, we mentioned that only 10 per cent of the world's land area is currently being cultivated but that at least 75 per cent of it could be used to grow food-producing trees. However, in the harsher areas, tree stands can be easily established only through the sowing of seeds. For example, if



the terrain is very rocky, sowing is the only feasible method. For these reasons, fruit tree plantations growing grafted trees are often established on lands that could be used for conventional farming with annual crops as well.

Because the seed-grown trees produce deeper and more extensive root systems than the vegetatively produced tree seedlings, they are more important for food security: they are less dependent on annual rainfall and more likely to produce food in drought years as well.

The higher yields produced by the proposed methods would be on a more sustainable basis than the yields of the modern systems, based on genetically uniform and therefore highly vulnerable monocultures. The proposed approach would produce a large number of very different high-yielding trees instead of large numbers of identical trees. Every single tree would be its own variety.

The proposed system would, unlike the modern system, have real significance in terms of carbon sequestration. A fruit tree plantation growing a large number of small trees does not absorb much carbon dioxide from the atmosphere. Even if there were about 2,000 trees per hectare, the volume of wood would be very small, if the trees were only a few metres high and if their trunks were very thin. But a farming system with 50 mango trees 40 metres in height and two metres in diameter would contain a lot of carbon in the roundwood alone.

The proposed system would provide a lot of employment for the local people on a permanent basis. In a system where the trees are small, the harvesting is easy and requires relatively little labour.

The establishment costs would be very small, because the trees could be established from seed. The annual cost of replacing old trees with younger ones would be minimal: many fruit tree species can maintain a high productivity for several hundred years, if they are grown from seed. Baobab trees can still produce fruit crops when they are thousands of years old. Grafted trees usually do not live for a very long time, and their productivity often starts to decline only after a few decades.

Many fruit, nut and pod tree species can also produce valuable timber. However, if the trees are grafted and kept low, small and

stunted with frequent pruning, no high-value timber will be produced. In order to get a high volume of good-quality timber, it is better to grow the trees from seed. The main purpose should be to produce food for human consumption, and the timber should only be a secondary consideration. But when an old tree stops producing fruit, or produces only very little, it makes sense to cut it down and replace it with a younger tree. In the process, a lot of timber with a substantial market value can be produced. This means that the traditional systems and the improved traditional systems could, unlike the modern systems, also become a kind of 'timber bank' for the poor households. A large old tree contains a lot of valuable timber that could be sold in time of severe need. A poor household could survive a famine or a serious accident by selling one of its trees as timber. No family, however, is likely to be directly affected by a famine if it has a couple of large, seed-grown and drought-resistant fruit or nut trees (unless somebody steals the crop).

Finally, this kind of breeding system would gradually produce, in every locality, trees that are better adapted to local conditions. If most, or all, the trees existing outside the research stations are clones of already existing superior specimens, the adaptation process slows down to a virtual standstill. If the trees are grown from seed, we will gradually get trees that are capable of withstanding severe drought or extreme cold. Moreover, we will get trees that produce better fruit and larger fruit crops than any of their ancestors.

There are, of course, also a number of problems. The method proposed above fits well for subsistence farmers or for people who produce fruit for the local market. But it may not always suit actual commercial production (except the production of raw materials for juices and other industrial products) because the quality and size of the fruit produced by each tree would be somewhat different. In commercial production, uniform size, shape and taste is often preferred, and any diversity is regarded as a negative factor. Another problem is that seed-grown trees take more time before they start producing fruit. This, however, can be partly compensated for by cultivating faster-growing food plants and, perhaps, also some grafted fruit trees on the same patch of land, while the seed-grown trees are still in their immature stage.



## Testing the Hypothesis in Practice

If you want to test the theory in practice with one or more tree species, the first thing to do is to look for superior trees. This can mean many things: like trees that produce very large fruit, nut or pod crops; trees which produce larger than average nuts or fruits; trees which have smaller than average seeds; trees which produce sweet fruit instead of fruit too sour for human consumption; or trees which have a better than average ratio between the edible and non-edible portions of the fruit. If timber production is a factor, you might look for trees that have both large fruits and a long, straight stem.

Some of the desired characteristics may be exceedingly rare, and very difficult to find, especially if the tree species in question is rare or endangered. One German plant breeder once had to investigate 1.2 million plant samples before he found eight individuals that contained the desired gene producing sweet edible plants.

Some of the trees that are being domesticated by a non-governmental organization called the Veld Products Research and Development (VPRD) in Botswana are now increasingly rare. The Kalahari bushmen can walk for days to visit a certain individual wild orange or monkey orange tree growing in the wilderness. Because VPRD collects superior specimens from an area that is approximately 60 million hectares in size, it has naturally been impossible for it to do all the work by itself. VPRD has solved the problem by organizing competitions in schools and villages. The person who finds the tree that produces the largest or sweetest fruits, or the best fruit crop, wins a small prize.

This rather innovative approach has produced very good results. More than 10,000 people, mostly school children, have already participated in the search for superior specimens, and the competitions have produced a lot of valuable genetic material.

Without the participation of the 10,000 volunteers, it would have been virtually impossible for the VPRD staff to cover the vast land areas which have now effectively been combed by the children. In most cases the children had been herding cattle or goats in the bush, and already knew the superior trees from their previous experience.

Somewhat similar methods have been, and can still be, used in other countries as well. A small professional team of scientists coming from another part of the world and making a quick seed-collecting roundtrip can never find the best specimens in the vast areas of land that ought to be searched. However, the materials collected for tree-breeding work have often been acquired through such missions.

After finding the superior phenotypes, you have to find how you can propagate the superior trees vegetatively (how to make exact copies or clones of them). Sometimes this is very easy, because many trees can easily be grown from cuttings taken from stems, leaves, leaf-buds or roots. The procedures you should follow differ from one species to another, so you should check what is the right method from someone who knows, or proceed through experimentation (through the effort and failure or trial and error method), if the species is less well-known. In dry or cold areas, it is often best to take cuttings during the dry season or cold season, when the trees are resting and do not have any leaves. If the trees have leaves, it is often a good idea to remove them so that the cutting doesn't lose its moisture content through the leaves before it has grown its own roots. With some species, it is a good idea to put the cuttings into water and let them grow some roots in it before you plant them.

In commercial production, a plant hormone called auxin (the rooting hormone of the plant) is often used in order to hasten the process of root formation. Many species that would not otherwise grow well from cuttings can be propagated this way if auxin is used.

Some species produce a lot of root suckers (shoots coming from its root system). Such species are very easy to propagate vegetatively: you only have to separate a root sucker and some of the adjoining root system from the mother tree and plant it in another place. Some species can be propagated from various specialized organs like bulbs, corms, rhizomes, tubers or tuberous roots that the plant is using for its own food storage.

However, many species do not produce root suckers, do not have suitable food storage organs and do not grow well—or at all—from cuttings. Such species are more difficult to propagate vegetatively, and require more complex techniques.



One group of vegetative propagation techniques involves the joining of two plant parts together so that they grow like one plant. The part consisting of the root system and a stem is called the stock plant (or rootstock). In grafting, a whole cutting is set into the rootstock, in budding, only a bud is used. The common name for buds and grafts is scion (*see drawings of processes on following pages*).

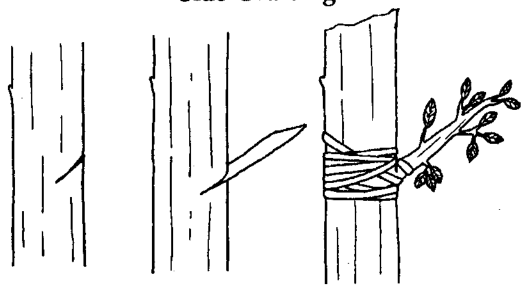
In grafting and budding, the rootstock and the graft (or the bud) are placed so that their tissues will remain in close contact and grow together before the surfaces dry. Large numbers of vegetatively propagated seedlings can be produced by these methods, which are especially useful in the propagation of species that are difficult to root. There are numerous different grafting and budding methods, but we will not go into the details here.

Another set of methods is called layering. Layering basically means that a shoot of a plant is encouraged to start producing roots (so-called adventitious roots) while it is still attached to the mother plant. When these adventitious roots are well developed, the shoot can be cut loose and separated. Layering is easier than grafting or budding, both of which require some practice and skill. However, layering is a very labour-intensive method, and only relatively small numbers of new plants can be produced. Also, the new plants propagated by layering tend to have shallow root systems. However, if we only want to establish a seed orchard, we do not have to worry about this.

In simple layering, a low, flexible shoot which bends freely is bent slowly to the ground and then buried in soil, five to seven centimetres deep. The tip of the shoot is left exposed, and the side shoots 15 or 20 centimetres from the tip are removed before the shoot is buried. The soil surrounding the buried shoots should be kept moist. In tropical conditions the rooting usually takes from five to seven weeks, in temperate zones, even two years are sometimes required. Some species root faster than others.

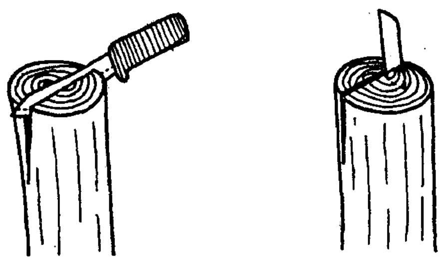
In trench layering, an entire branch or plant (sometimes even a whole tree) is bent slowly into a shallow trench and covered with five to seven centimetres of soil. As the shoots emerge, more soil is put on top of them so that they do not get any light, and start to

### Side Grafting



A slanting cut is made in the root stock (the tree with the roots). A section is inserted in the cut. The stock is cut back when the scion has started to grow.

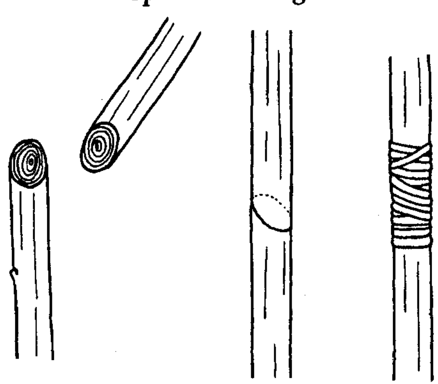
### Cleft Grafting



Vertical split is made on stock

The split is held open with a wedge, the prepared scion is inserted and the wedge is withdrawn.

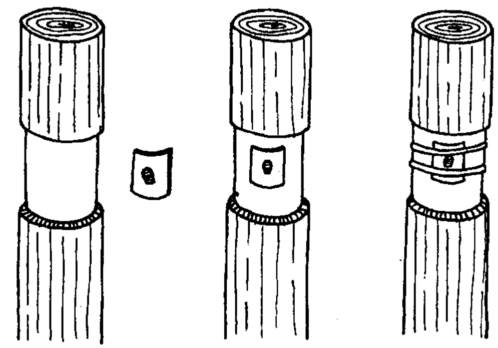
### Splice Grafting



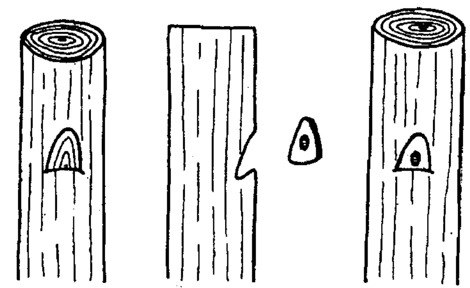
The stock and the scion are cut so that their surfaces match perfectly, then placed together and tied together with tape.



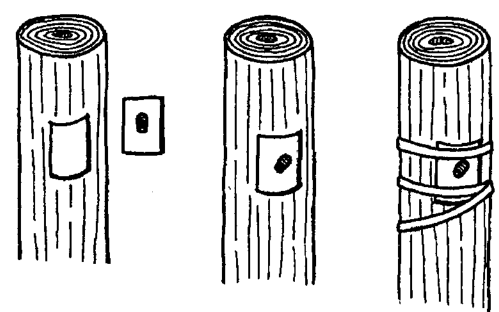
### Ring Budding



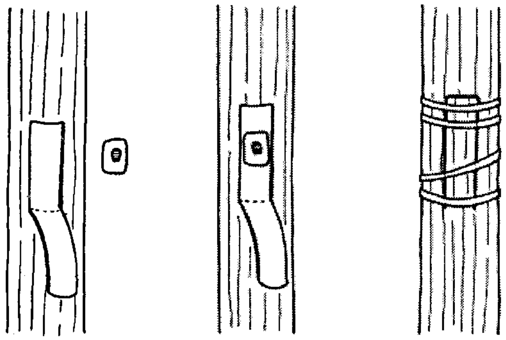
### Chip Budding



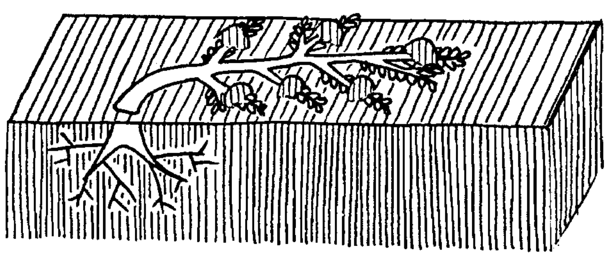
### Patch Budding



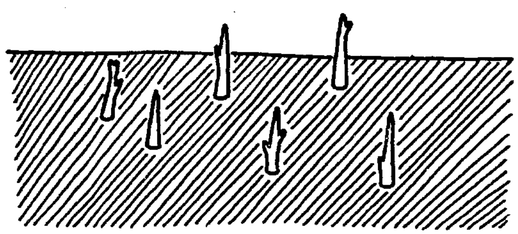
## Budding by the Folkert method



## Trench layering



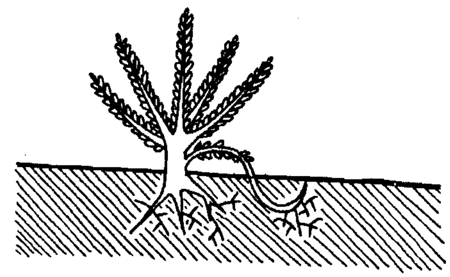
In trench layering the whole mother plant is bent down
on the bottom of the trench, pegged down
and covered with soil.



When new shoots emerge, soil is added to cover their bases.
Finally the soil is removed and the rooted shoots
are separated from mother plants

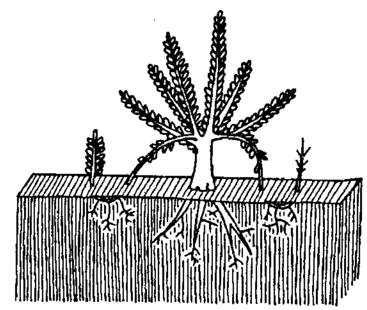


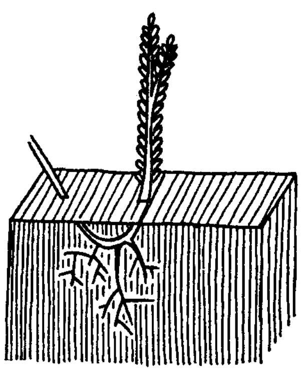
## Tip Layering



In tip layering the current season's shoots are used.

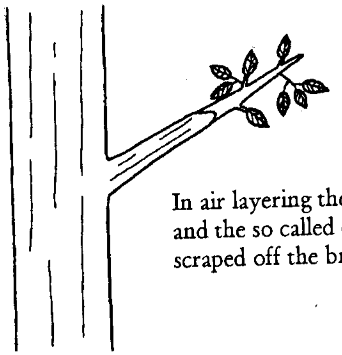
## Simple layering





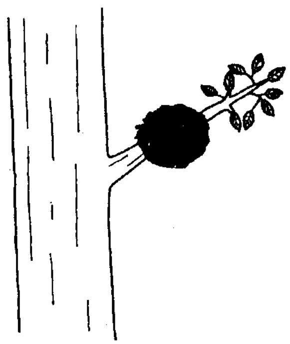
After the buried part has grown its own roots
it can be transplanted.

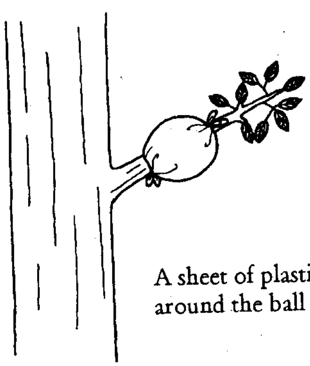
## Air layering



In air layering the bark is removed and the so called cambium layer scraped off the branch.

A ball of moist sphagnum moss or soil is placed around the ring-barked section.

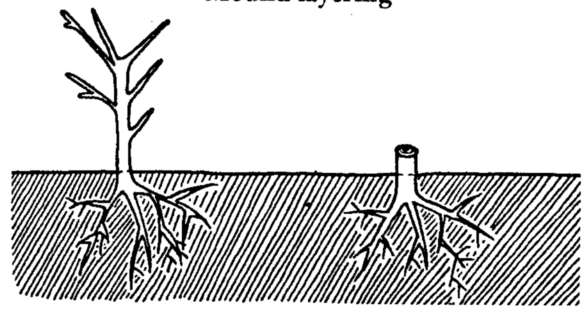




A sheet of plastic is wrapped around the ball of moss (or soil).

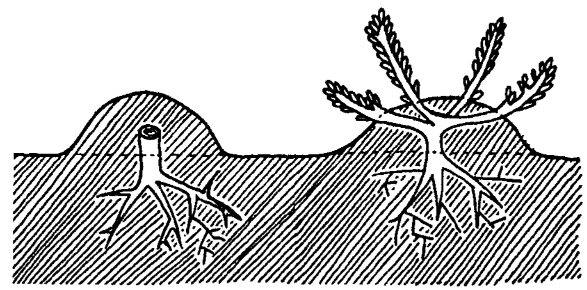


## Mound layering



1. 2.

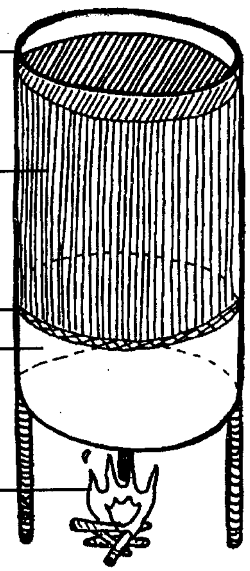
In mound layering the top of the mother plant is removed and the stump is covered with soil.



3. 4.

5.

If the mother plant /tree is small and bushy it can be buried as a whole, without removing the top.




The soil sterilisation method used by VPRD and CED in mycorrhiza studies. Water heated by the fire becomes steam that kills all mycorrhiza spores in the soil. After the soil has cooled, the spores of the desired mycorrhizas can be introduced.



produce roots. When rooting is complete, the soil is removed and the rooted shoots can be separated from the mother plant and transplanted.

In air layering, fairly long, partially hardened, one-or-two-year-old shoots are used. All the leaves of the shoot, except the first few ones near the tip, are removed. The shoot is ring-barked: all the bark is removed from a length of 1.5 to 2.5 centimetres. Moss or moist soil is placed around the ring-barked section of the shoot, and a transparent plastic sheet is wrapped around it. The ends of the sheet are twisted and tied tightly. The plastic prevents the moisture from escaping, and roots should develop within 30 to 45 days in tropical or subtropical conditions. In India, the ideal time for air layering is early spring, or the onset of the monsoon.

In mound layering, the stem is cut back to a height of 10 centimetres above the ground level (during the dormant season). When the shoots emerge, they are buried. When they emerge again, more soil is added on top of them. The soil is kept moist in order to encourage the rooting.

The first aim should always be to grow a small plantation of trees, each of which is—genetically speaking—an exact copy of a superior tree found somewhere in the wild, or in a farmer's backyard. When the trees grow and start to produce fruit, we may find that some of the superior trees were only superior phenotypes and not superior genotypes. The quantity and quality of fruit produced by a tree is influenced by a combination of genetic and environmental factors. Even if a tree is producing a good crop, this doesn't necessarily mean that it has superior genes. It may be that the large fruit crop is mostly caused by environmental factors. It may, for instance, be that the tree is growing at a very favourable site. The site may have been a large termite mound, which means that there is a lot of natural fertilizer in the soil. Or it may be that there is an abundant underground source of water.

The characteristics visible in a tree, caused by a combination of environmental and genetic factors, form a phenotype. A genotype refers to the characteristics that are of a genetic origin, and not caused by environmental conditions.

When the vegetatively propagated clones of various superior trees are planted in a garden, the unfair advantages from environmental factors are eliminated. This means that the trees whose fruit crops were based on favourable environmental conditions do not perform very well. But the trees whose desired characteristics were based on genetic factors should produce good crops even in the new location. We should keep such trees and remove the rest.

In an official, scientific plant-breeding station, pollination (fertilization) is done by technicians with tweezers, so that it is known exactly which tree has fertilized a certain flower. Scientists keep precise records of the lineage of each individual. If we really want to wipe out the genes producing undesired characteristics, we should follow this procedure. It is the only way to find out which of the parent trees contain and which do not contain recessive genes causing the undesired characteristics. We shall come back to this a little later.

However, if our aim is to produce genetically diverse stands of trees, we do not necessarily have to be quite as precise as this. If all the trees growing in our seed orchards have the desired characteristics, we can let them fertilize each other randomly, just like it would happen in nature. If all the trees are carefully selected superior genotypes, and if there are no inferior trees of the same species growing nearby, the seed produced by our trees should mostly produce good-quality offspring.

As mentioned before, the desired characteristic (caused by only one gene) visible in a tree can be caused either by two recessive or two dominant genes in both parents; by two dominant genes in one and one dominant gene in the other parent or by one dominant gene in each parent. Only in the last option is there a chance that some (25 per cent) of the offspring will not contain the desired characteristic.

Let's say that we are interested in three characteristics, which are: large fruit crop, large size of the fruit and the sweetness of the fruit. We have selected only trees that contain all the desired characteristics. Let's assume that the large fruit crop is not, in reality, an important quality, because all the wild trees produce heavy fruit crops. So, in practice, we can concentrate on two qualities. We will



also assume, in this example, that none of the important characteristics are inherited together, and that they can thus be separated by selective breeding.

To be on the safe side, we can start with the worst option, and assume that both parent trees have a recessive gene that causes sour fruit, which means that 25 per cent of the first-generation offspring will produce sour fruit. (If only one or neither parent had such a gene, none of the trees would produce sour fruit.) Let us also assume that both parents have a recessive gene related to small fruit size. Because both parents have both undesirable, recessive genes, only nine out of 16 of the trees growing from their seed will produce large and sweet fruit. Three produce large but sour, three sweet but small and one small and sour fruit.

If our gardener is only interested in large and sweet fruit, he has grown seven useless trees for each nine useful trees. However, there are at least two easy solutions to this problem. One is to begin with more trees that can finally remain on the plot. This can easily be done, because small trees require much less space than mature ones. Also, the price of seed-grown trees is much less than that of grafted seedlings. If you establish the trees from seed yourself, you only need to purchase or acquire the seed.

This way you can start, for example, with 1,600 trees per hectare and remove up to 700 of them, when you can see which ones do not contain all the desired characteristics. Such a method, however, may contain some opportunity costs, because it limits the possibilities for growing other crops between the trees while they are still small.

Another possibility is to establish the actual seed lots only after identifying and eliminating the trees that contain undesired recessive genes. Official plant breeders wrap some of the female flowers of the superior trees with plastic or with pieces of canvas, in order to prevent random pollination by insects (or by wind, if the species is pollinated by it). Then some pollen is taken from the male flowers of another tree and put into the protected female flowers. Other female flowers of the same tree are fertilized with pollen taken from the male flowers of another tree, and so on. Everything is recorded, meticulously and precisely.

We now know both the parents of the trees grown from the seed produced by the artificially fertilized flowers. The characteristics of the first-generation offspring already tell us a lot. If all the trees produce only the qualities we have been hoping for, we know that their parent trees (or clones of them) can only produce first-generation offspring that always have the desired characteristics. This means that the parent trees (or clones of them) can be used as mother trees in seed lots with very good results. We cannot yet promise that this would apply to their grandchildren as well, because one of the parents might still have an undesired recessive gene.

However, if we have done a number of experiments with different trees, the results of the other trials might tell us whether this is true or not. To make sure, we can cross some of the first-generation offspring with each other. If the undesired characteristic doesn't appear in the second generation, we can safely assume that our seed is a stable variety and breeds true from generation to generation—in terms of certain characteristics. If we want to breed more stable characteristics into our seed, we need more generations to do this—and much more space for the trials. But as long as we are only dealing with a few qualities, the effort is manageable even on a small farm.

### Where to Stop?

How far can we go without getting the same problems of genetic uniformity and increasing damage from pests and plant diseases that are now affecting the conventional farming systems?

As we have started from a very wide genetic basis, and because we have limited the use of cloning (vegetative propagation) to the stage of seed production, we should be able to continue the selective breeding of our trees almost indefinitely without narrowing the genetic basis of our tree crops too much. If we always grow the new trees from seed, there is no risk of producing genetically uniform monocultures.

If the breeding efforts emphasize high-quality fruit and large fruit crops, we will, from generation to generation, get better and better fruits and a little larger fruit crops. But this does not mean that we are producing genetically uniform tree stands. On the contrary: we are doing what the ancient farmers did, and creating thousands or millions of different, high-yielding varieties that can otherwise be genetically very different.



When the trees are grown from seeds, they will keep on cross-breeding and mutating and becoming hybridized with other closely related species, and switching some of their genes off and other genes on with the help of the so-called suppressor genes. When the trees are grown from seed, they will continue adapting to new conditions and circumstances. They will adapt to more intense drought, cold or heat, become more resistant to salinization, invent novel ways to fight new strains of disease and predators, and so on. The only way to stop this natural process of evolution is to continue cloning the same old tree specimens (individuals) over and over again.

In the present breeding system, a handful of scientists try to do the job of God, to compete and beat the evolutionary forces successfully. In the long run, this method doesn't have much chance of succeeding. It is much better to let evolution work for us and to work with nature, instead of trying to work against it. By adapting an integrated breeding system, we could soon have, at least in theory, three billion food tree breeders—all the farmers and gardeners in the world—instead of only a few thousand, working in their research stations and laboratories.

For more than 10,000 years, all the progress in plant breeding was based on the work of ordinary farmers planting and growing and selecting and domesticating various fruit trees and other useful plants.

A situation in which the governments and commercial companies try to exclude the farmers and gardeners from the plant-breeding work, and monopolize it as a privilege of a handful of scientists and commercial companies, has produced large profits for some, and created some short-term benefits for the majority of the people. But it has also derailed our whole food production and food plant-breeding system, pushing it onto an unsustainable road that will inevitably bring us to a dead end, sooner or later.

With 100,000 times more man-power made available, by encouraging all the farmers and other people practising gardening to once again become food tree and plant breeders, we could do so

much more. We could develop innumerable varieties of thousands and thousands of different food-producing trees and other useful plants.

India and the other South Asian countries could play a very important part in such efforts. South Asia has already provided the world with many of its most useful food plants and fruit trees, and there is no reason why the region should not have a similar role in the future too. India, alone, has all kinds of vegetative and climatic zones from humid and sub-humid to semi-arid and arid, and from tropical and subtropical, to temperate and alpine, high in the Himalayan mountains.

Practically all the food-producing trees growing anywhere in the world can be grown somewhere in India, which means that India and the other South Asian countries could lead the breeding of both thousands of domestic and thousands of exotic food-producing tree species. This could also contribute, in a major way, to the preservation of the biological diversity of all these species.

Chapter Four of this book, which introduces some of the more interesting tree species, hopefully gives an idea about the potential benefits that could be gained through such efforts.

The great majority of potentially valuable species have received little or no research attention. Even in the case of the species that have received the most intensive attention, the breeding efforts have used all the typical short cuts, over-emphasizing vegetative propagation (cloning) and seriously diminishing the genetic diversity of each species.

With new species that have never been domesticated before, the first steps are always the most difficult. While starting the domestication of a new, potentially valuable species, the contribution of a single but determined individual can often be decisive. You can achieve a lot by choosing a promising tree, or a genus of trees, and starting to work on their domestication and improvement. Often, the lifetime of an individual will not be enough, and you will not be able to see the final fruits of your own work. But you will still know that you have probably started something valuable, and other people will continue the work from where you leave it.

In one way, however, our own time must remain unique. The presently existing vast diversity of hundreds of thousands of differ-



## The Girl Whose Lover Was a Tree

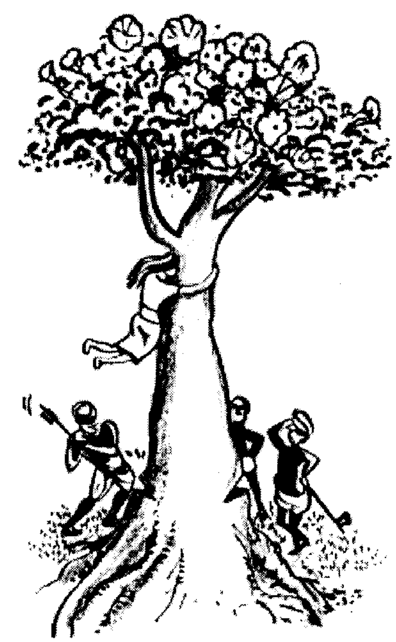
Once upon a time, there was a rich man who had a beautiful daughter. Many men wanted to marry her but she refused them all. The girl lived in a dormitory with all the other marriageable girls of the village. Her heart had been given to a youth who used to come to her secretly every night in the dormitory and leave at dawn. During the day, the girl hunted for her lover in the village but she could never find him. At last, she told her parents about him. The father was determined to find out who his daughter's lover was. So, one night, he hid himself outside the dormitory and kept watch.

The youth entered the dormitory silently. At dawn he came out. The father followed the man. Instead of going to his own dormitory or *gorung*, the youth headed outside the gate of the village and towards the spring. As soon as he reached the water a strange transformation took place. His arms turned into branches, his hair into leaves and his earrings into white clusters of flowers. Soon, instead of a man, there was a tall tree.

The father was determined to cut down this magic tree, so that his daughter could marry a normal human. He called all his friends and relatives to help him. They cut and cut, but the tree would not fall. But after much chopping and cutting, it at last came down with a crash. In the moment of its death, one wood chip flew far. It reached the girl, pierced her through the eye and went right through to her brain.

The father, rejoicing at the destruction of the tree, came back to his hut only to find that the two lovers had died together.

*—Chongli tribal legend from Nagaland*



ent tree and plant species and their billions of different varieties is the result of hundreds of millions of years of natural evolution. There is a great risk that most of these treasures will be destroyed, permanently, within our own lifetime.

The world's human population has risen from three to six billion between the years 1960 and 2000, and it will be likely to rise to eight or nine billion during the next 40 years. It seems that the world has lost or will lose most of its original natural forest cover within a period of time that is shorter than a century. After this, all that remains are the species and varieties and superior specimens of each species we have been able to save. All the rest will be gone — forever.

The human species (*Homo sapiens*) has now existed for about 100,000 years. The human genus (*Homo* spp) is thought to be approximately two million years old. According to one estimate, between 50 and 100 billion human beings have been living on earth during these 50,000 or so generations. The great majority of all these men and women have received a major part of their diets from various food-producing trees. Agriculture has been practised only during the last 0.5 per cent of human history and, even after the birth of agriculture, tree crops have still had a lot of importance in human diets.

We do not know how long the human species will continue to inhabit planet earth. With some luck, our descendants might well survive for another 50,000 generations, perhaps even longer. Mammal genera have often survived for tens of millions of years.

During 99.9 per cent of human history, the earth has been inhabited by only a few million human beings. In our time and in the future, the human population of our planet will be counted in billions. This means that the number of human beings that will be living on our planet in the future is likely to be vastly larger than the number of human beings that have thus far been born, lived and died on earth.

If we are able to save the most promising and important wild trees producing edible fruit, berries, nuts, seeds or pods, and breed innumerable useful varieties of each species, our work could bring with it a lot of joy and great benefits to the coming 50,000 or so future generations, to perhaps the 100 million people yet to be born.

# 4

# Important Tree Species

In the following pages, a number of tree species and genera that are especially important from the viewpoint of this book are introduced. Besides the botanical and horticultural information, attention is also paid to the mythological aspects of the trees that have major cultural importance in South Asia.

The main emphasis is on species that produce large quantities of nutritious food and grow to a substantial size (so that they can produce large storages of organic carbon per hectare). The main assumption is that the trees that are used in carbon storage forestry should also produce food for human consumption. However, some smaller trees that have a lot of importance for food production have also been included, as well as some species that do not produce any food for humans (besides edible mushrooms) but which might still have some importance as carbon storage trees because of their very large size.

There are some notable omissions from the list. For example, oranges and other citrus fruits (*Citrus* spp) have not been included, in spite of their large economic significance. This may sound odd, but from the viewpoint of this book, the various citrus species are

not important. They are small trees that do not have much significance in carbon sequestration, and the nutritive value of the fruits in terms of protein and calories is very low. All the food-producing trees mentioned in the following list produce far more nutritious fruits, nuts or pods. When it comes to palm trees, even the sap of some species is more nutritive than the fruit flesh of many citrus species.

The list includes a lot of trees producing nuts, seeds or pods that most people would not classify as edible or as food for humans. For example, the pods of many leguminous trees, acorns and beechnuts are in this category. They are, in theory, edible, but a lot of work is required to prepare them as food.

However, we should keep in mind that most of the food we now eat, and whose edibility we take for granted, requires at least the same amount of processing before it can be eaten by humans. Grain cannot be eaten as it is: it must first be hulled and ground and baked or cooked. Cassava must go through quite a complex process before it can safely be eaten. Beans must be soaked in water and boiled.

It may be that when we think of food from the trees, we tend to think in terms of edible fruits or nuts, things that can be eaten as they are, and not in terms of raw materials for bread, porridge or edible oils.

If we classify as 'food' all the seeds, pods, nuts and fruits produced by trees that require, at most, the same amount of processing as most cereals to be fit for consumption, we can note that even our already existing forests produce truly enormous amounts of nutritive food. Actually, it is likely that the trees growing on earth currently produce, in terms of calories and proteins fit for human consumption, more food than agriculture, even though only a negligible part of all this food is actually used to feed humans.

The claim may sound ridiculous, but we only need to take a quick glance at the various ecosystems of the earth to conclude otherwise. In the temperate zone, much of the tree cover consists of trees producing seeds, nuts or berries that could be eaten by humans: beeches, oaks, chestnuts, walnuts, rowans, limes and so on. In the huge Siberian evergreen forest, one of the dominant tree species is the cembra pine, that produces very nutritious edible seeds. The northern tundra and peatlands are often covered by shrubs producing large crops of edible berries. In the drier parts of North, South and Central America, the vegetation is often dominated by prosopis trees, whose pods can be ground to edible, protein-rich flour, or by cacti that produce both edible fruits and edible cactus flesh. The huge miombo forests covering hundreds of millions of hectares in southern and eastern Africa, typically provide a couple of tonnes of wild, edible fruits per hectare. Natural rainforests produce large quantities of different edible fruits. The palm forests of Africa, Latin America and Asia yield edible fruits, starch, palm hearts and sap. The sal forests of South and Southeast Asia give us seed that can be eaten as it is or used as raw material for vegetable oil. To this should still be added the edible mycorrhiza mushrooms grown by the root systems of trees and the berry-producing shrubs of the forest undergrowth.



Needless to say, the food production of the natural forests and of the wild trees growing in them, could be increased substantially through suitable management practices and by breeding strains that produce, on average, larger quantities of food than the wild specimens.

## The Palm Family (Palmae)

The palms are definitely one of the most important and useful families of plants. The family includes altogether about 3,500 members, most of which are trees and some of which, for example, the rattans, are climbers.

From the viewpoint of storing atmospheric carbon dioxide, the palm trees have one major drawback. Instead of growing huge, thick, wooden trunks the palm trees become taller without growing thicker. This drawback is, to some extent, compensated for by their almost unsurpassed litter production. For example, the wild babassu (*Obrignya phalerata*) forests of Brazil produce, on average, 25 tonnes of litter per hectare per year (counted as dry matter). Because of their high litter production, the palm forests effectively improve the quality of the soil and store large amounts of carbon in the litter and humus layer. Moreover, palms growing on the tropical swamps

might be an alternative for draining the peatlands, which could prevent very large carbon dioxide emissions.

At least three species of palms have worldwide economic significance. These three are, the coconut palm (*Cocos nucifera*), the date palm (*Phoenix dactyliflera*) and the oil palm (*Elaiesis guineensis*).

The coconut palm is sometimes called the Tree of Heaven because of its many uses. The leaves are used for thatching roofs, the trunk for small boats. The sap of the tree yields a juice called toddy, which is made into alcohol and also sugar. Brooms are made from the leaf ribs. The fibre from the husk is called coir and is used for ropes, carpets and stuffing. The shell is used for fuel and for scoops. It is also burnt and made into black paint. The kernel or copra is eaten fresh or used for curries or made into oil. It is also used to make soap and margarine.

In south India, the coconut is called Green Gold. During the Second World War, soldiers were given transfusions of coconut water, as it was considered sterile.

The species most probably has its origins in South and Central America, where there are many related wild members of the same genus. However, it has since then spread throughout the humid and sub-humid tropics. The coconut provides nutritious food, refreshing drink, edible oil and fibres for commercial use. The palm also provides fuel and timber, and there are numerous different uses for the hard shells. Coconut oil currently satisfies about seven per cent of the vegetable oil consumption in the world.

The information available of the area and production of coconut is not very accurate. R.S. Mishra and B.K. Pattanayak have estimated that some time ago coconut palms were grown on approximately nine million hectares, and that the world production might have been around 40,000 million nuts per year. However, according to them, the present figures should be much larger, because people all over the tropics have been planting a lot of coconut trees during the last few decades.

The yield of nuts and copra is highly variable. The best recorded yields have been around 150 nuts per palm, with an average of 200 grams of copra per nut, and with a 70 per cent oil content in the



copra. Such trees can produce up to 5.5 tonnes of copra per hectare. However, other trees may only produce 20–30 coconuts per year. The calorific value of copra is slightly higher than that of rice, or five times that of potatoes. Also, the coconut milk is relatively nutritious.

Coconut palms are often grown as upper-storey trees, under which smaller trees and other crops are grown. Coconuts tolerate high levels of salinity, which increases their importance in the coastal areas.

*Cocos* means 'grimace' in Portuguese, as the fruit is said to resemble a monkey's head and the three holes at the nut's base give it the look of a grinning face. *Nucifera* means 'nut-bearing'. The Sanskrit word *Narikela* comes from the root *Narik* which means 'with water'.

On the Hindu New Year, it is considered auspicious to see a coconut immediately on opening one's eyes. The Bengalis believe that a coconut has eyes and will never fall on the head of a passer-by. In Gujarat it is a family god. The Muslims of the Deccan (south India) throw cut coconut and lime over the heads of bridegrooms to scare away evil spirits. In western India, coconuts are thrown into the sea at the close of the monsoons to satiate and pacify the waters. Because a coconut resembles a human head, it was offered to Goddess Bhadrakali instead of a human sacrifice.

The oil palm is one of the most important sources of food oil in the world. It produces the highest known yield of vegetable oil. The average annual hectare yield of oil has been between three and four tonnes, but it seems that yields exceeding seven tonnes are becoming more common. For every tonne of oil extracted, two or three tonnes of effluent are also produced. The effluent contains 10 per cent crude protein, 20 per cent fat and 47 per cent carbohydrates, and has numerous food, fodder or fuel uses. Palm oil in itself contains only insignificant quantities of minerals. However, the fruit bunches contain a lot. This means, that if the remnants of the fruits, and the nutrients contained in them, are not recycled back to the plantations, they have to be fertilized heavily in order to maintain a high level of productivity.

Large oil palm plantations have been established throughout the humid tropics. Besides the plantations, oil palms also form extensive wild, high-density stands on secondary forest sites in West Africa. In spite of the great value of the coconut and oil palms, they have one problem from the viewpoint of public health. Both produce oil with a very high content of saturated fats that can contribute to the development of cardiovascular disease.

The date palm is the most sacred tree for the Arabs. This is easy to understand, because it was, for thousands of years, the only domesticated food-producing tree that could survive in desert conditions. One date palm can produce up to 200 kilograms of fruit that have a very high sugar content, plus some fat and protein. The annual hectare yields in intensively managed and selected stands are between 10 and 20 tonnes. Dates can be eaten fresh or dried and stored for a long time. The sap can be used to make wine or palm sugar. Date palms are often used as upper-storey trees and grown in association with other crops. According to old Arab scriptures, the date palm has a total of 800 different uses.

Several other species have also been cultivated on a smaller scale. The palmyra palm (*Borassus flabellifer*) has major significance in southern India. It has been estimated that there are about 80 million palmyra palms in India, 50 million of which are in the state of Tamil Nadu. The palmyra palm tolerates dry conditions better than most other palms: it is usually grown where it is too dry for the coconuts, which require at least 1,000 millimetres of rain annually. The palmyra palm does well in areas where the annual rainfall is at least 600 mm, but it can survive with 200 mm, if the level of the groundwater is not too low.

The palmyra is grown for its sugar-rich sap and for its fruit. One palm typically yields between 80 and 100 fruit, the weight of which varies from 0.5 to 5 kilograms. The average annual fruit yield is 50–100 kilograms per tree, or 5–10 tonnes per hectare, because the palmyra are usually spaced within a distance of 10 metres from each other. The sap contains 12 per cent sugar, and the annual yield per tree varies between 300 and 450 litres. The sap, or *neera*, can be used either in the making of palm wine (toddy) or to make palm sugar. Palmyra palms can remain productive for more than 100 years, and they can reach a height of 30 metres.



The Indian sago palm or the fish-tail palm (*Caryota utens*) is also a very useful species. One palm produces, on average, 800 litres of palm wine in a season. A sago-like starch can be obtained from the stem, and made into bread or porridge.

The so-called borassus palm (*Borassus aethiopium*), the tallest native palm of Africa, is a close relative of the palmyra. The borassus palm produces sugar-rich sap and good crops of large fruit, with an average diameter of 15 cm. The pulp of the fruit is edible.

The wild date palm (*Phoenix reclinata*) is an African relative of the date palm. It grows in dense clumps near swamps or rivers, and produces edible fruit that resemble the domesticated dates, but are slightly smaller.

One of the largest known palm trees is the Chilean wine palm (*Jubaea chilensis*). It grows slowly, but can become 30 metres tall and reach two metres in diameter, which is a good achievement for a palm tree. The sap can be used to make wine. The species grows wild only in a very small area of Chile, and even there it is now almost extinct. However, it has been planted as an ornamental tree in many countries.

In the Amazonian rainforests, indigenous peoples have cultivated pejibaye, or the peach palm (*Bactris gasipaes*) for hundreds of years. Peach palm is one of the tree species which might have a very bright future as a food crop for tropical rainforest areas. Both the fruit and the palm heart are edible, and the plant is also a good source of nutritious vegetable oil. According to J.A. Samson:

> Tropical America is particularly rich in palms with edible fruits. The leading one is the pejibaye... It is one of the most balanced tropical foods and contains twice as much protein as the banana. Thirteen bunches of fruit, each about 12 kilograms, can be harvested twice a year and the tree can live for 75 years.

By selecting individuals with the desired characteristics, the rainforest Indians have bred at least 200 distinct types of the peach palm.

In Bolivia, the Indians concentrated on developing the oil content of the pejibaye; in Colombia, Peru and Bolivia, they bred palms that have a good nutritional value as a staple food. Some varieties contain up to 15 per cent of protein. The pejibaye is usually grown

## The Prince and the Peacock Fans

Once upon a time there lived a rich merchant who had seven daughters. He was very arrogant about his wealth and lost no opportunity to show it off. One day, lacking an audience, he called his seven daughters and asked them: 'Whose fortune keeps you alive and happy?' Six daughters replied: 'Yours, Papa.' But the youngest was wilful and she said: 'I am alive and happy because of my own good fortune.'

'Very well,' said her angered father. 'Let me see how far your good fortune carries you, Miss.' He called his palanquin bearers and sent her away to the dense forest. He allowed her to take only her box of sewing needles and thread and an old nurse who had been with her since she was born.

The two women were set down at sunset at the foot of a very large teak tree. The palanquin bearers saluted them and were gone.

The gigantic teak tree looked down at the little fourteen-year-old crying with fear. 'Unhappy girl,' it said, 'soon the wild beasts of the jungle will come and eat you up.'

But as it spoke, the girl looked so piteous that its heart softened. 'All right, don't cry. I will help you. I will open my trunk and both of you can hide in it.'

The teak split its trunk and the girl and her nurse climbed into the hollow. The tree closed back into its natural shape. The wild beasts came out at night. Prowling round the jungle, they smelt humans. 'We know you are hiding humans within you,' they howled at the teak tree. They dashed against the tree, clawed its bark into shreds, broke its branches and scattered its leaves. But the tree would not surrender the fugitives, even though blood ran from its pierced bark.

As dawn broke, the wild beasts returned to their lairs. The exhausted tree split open and the two women came out. They saw the gaping wounds of the tree.

'Good tree,' said the girl and embraced it. 'You have given us shelter at a heavy cost. We are grateful.' She went to the banks of a nearby river and brought back fistfuls of mud which she smeared on the open gashes of the trunk.

The tree felt better. 'But you must be hungry,' it said to the girl. She nodded.

'Give your nurse whatever money you have and let her go to the city and buy some khai (roasted rice).' The girl took out a few needles and some golden thread from her sewing box and gave them to her nurse to sell in the city.

The nurse came back with a small sackful of khai. 'Eat only half of this,' commanded the teak tree. 'Strew the rest on the bank of the river.'

The women did as they were told, even though they did not understand why, and then they climbed back inside the tree trunk to sleep.

Flocks of peacocks always came to the river at night. When the birds saw the khai they went mad with delight and struggled and pushed one another to peck each delicious piece of rice off the ground. In this jostling, many of their tail feathers fell off.

When morning came and the women emerged from the trunk, the tree told them: 'Go to the riverbed and gather the peacock plumes that you can see lying there. Stitch these plumes together into a fan for the king of the city.'



The girl sewed the plumes together and the nurse took the fan to the city palace. The king's son saw the fan, liked it and immediately bought it. 'Did you make it?' he asked the nurse. 'No,' she answered, 'my little mistress is extremely skilful with her needle and she made it.'

With the money the prince had given her, the nurse bought some more khai and again half of it was eaten and half strewn on the bank of the river. Every night the peacocks came and every morning the little girl had enough feathers for a fan. The nurse took the fans to the palace, where they had become very popular with the prince's friends, and sold them to the court.

Every time she met the prince he questioned her about her mistress. 'Won't she come to sell them herself?' he asked. 'Oh no, Sir,' answered the shocked nurse, 'my mistress is extremely well born. She would never come to the market.'

With the money that the fans brought, the girl built a little house near the teak tree. She lived there with her nurse. But the prince grew more and more curious about the dextrous seamstress and one day he followed the nurse back from the city and saw the girl. She had grown slender and beautiful. He decided to marry her.

The king and his court came to the forest, for the girl refused to be married anywhere else. The ceremony was held below the teak tree which was decorated with garlands for the occasion. The bride and groom poured milk at its roots. The merchant and his daughters came for the wedding too. And all thanked the teak tree for its wisdom and care.

mixed with other fruit trees and other crops. The cultivation is easy, because the plant is 'practically a weed'.

According to C.R. Clement and H. Villachica, the Amazonian peach palm plantations can yield up to 30 tonnes of fruit per hectare, annually. Compare this, for example, with the 50 kilograms of meat annually produced on one hectare by cattle-ranching in the rainforest areas. In other words, peach palm plantations can produce about 500 times more protein and calories suitable for human consumption than cattle-ranching. And this is a short-term comparison. In the long run, the difference is still much more dramatic. If the nutrients are recycled back to the farming system, tree crops can be grown on rainforest land on a permanent basis, for thousands and thousands of years. In theory, it should be possible to continue this kind of cultivation almost forever: some of the rainforests have probably existed for 100 million years or more.

Besides the domesticated palms, the wild palm forests often have major significance for the people. Tropical forests are usually characterized by very high diversity, but there are also indigenous tropical forests that are dominated by palm trees, often belonging to only one species, which have a very low biological diversity.

Babassu forests in the state of Maranhao in Brazil are a superb example of this phenomenon. Babassu (*Orbignya phalerata*) is the South American counterpart of the African oil palm. The almost pure, dense babassu stands cover 10 million hectares and contain about 2,000 million babassu palms. Babassu forests are of great importance for the local people. The leaves are used in the making of baskets, mats, fans, sieves, twine, thatch and a number of other products. The fruits look, taste and smell like coconut, but contain 70 per cent more edible oil than coconuts. The seed cake that is left over after the oil has been extracted is very rich in protein. The husks can be burned or can be used as raw material for making charcoal. The extraction of kernels from the very hard fruit provides 500,000 rural families with a significant part of their income.

The above-the-ground biomass of the babassu stands contains, on an average, about 150 tonnes of dry matter per hectare, which would correspond to about 75 tonnes of organic carbon. This is not a very high figure. Babassu palms are not tall trees and they do not



have heavy trunks. However, the amount of carbon stored in the litter and humus layer is probably greater, because the babassu stands have a very high litter production. Almost half of the total biomass of the babassu stands (69 tonnes per hectare) consists of leaflets and leaf axes, which is rather exceptional. The annual fruit production of the wild stands is little more than three tonnes per hectare, when counted as dry matter.

The nipa palm (*Nypa fruticans*) is probably one of the oldest angiosperms or flowering plants. According to fossil discoveries, it was growing almost everywhere in the tropics 13–63 million years ago. Since then, it has disappeared from Africa and Latin America, and now grows only in the saltwater marshes (mangrove swamps) of Southeast Asia and Oceania. Nipa stands have, during recent decades, been continuously cleared for rice, shrimp and fish farming.

For example, on the Malaysian peninsula the acreage covered by the nipa forests was reduced from 11,300 to only 2,300 hectares between the years 1969 and 1977. The largest stands can now be found in Indonesia and Papua New Guinea, where the nipa forests still cover 700,000 and 500,000 hectares, respectively. The wild, often almost pure stands contain up to 10,000 plants per hectare, though the average density is between 2,000 and 4,000 plants.

The nipa is not a very large palm, and does not grow more than 10 metres high. The leaves of nipa palm have traditionally been used as thatching material for houses, and as raw material for baskets, brooms and sun and rain hats. But the nipa palm is also a very efficient producer of raw material for sugar. A hectare of nipa palms yields between 120,000 and 170,000 litres of sap in a year. The sap contains between 12 and 16 per cent sucrose, which corresponds to a yield of 15–20 tonnes of sugar per hectare per year. Counted as calories fit for human consumption, this is equivalent to an annual potato yield of 75–100 tonnes per hectare. Sugarcane, which is often considered the most efficient producer of calories among the presently cultivated plants, only produces an average of nine tonnes of sugar per hectare per year, and to achieve such crops, large amounts of fertilizer and pesticides are required.

The sap can also be used to produce syrup, acetic acid, vinegar or (fuel) alcohol. If the sucrose is converted to alcohol, the annual yield is about 11,000 litres of pure alcohol per hectare.

The cultivation of nipa palms is easy. Nipa stands can easily be grown from seed, and they need almost no care or management.

The sago palm (*Metroxylon sagu*) grows in the freshwater swamps of Southeast Asia and the Pacific islands. Sago trunks are filled with edible starch, which is the staple food of several indigenous peoples in Indonesia and Papua New Guinea. Sago gives a better yield of food compared to the amount of labour required for almost any other crop. Like babassu and nipa, sago stands are self-propagating. They grow by themselves in the swamps, where the different weeds do not have a chance to compete with them. Because the crop (the starch) is protected by the trunk of the palm, no pesticides are required.

The yield of sago is very reliable and there is hardly any annual fluctuation in it: an average annual crop amounts to about 15,000 kilograms of starch per hectare. A sago palm grows for 10–15 years before it starts to flower and then dies. The starch is extracted from the mature trees by splitting the trunk just before the flowering starts. The calorific value of sago starch is four times higher than that of potatoes (1500 kJ/100 g). This means that in terms of calories, the annual hectare yield of sago is equivalent to 60 tonnes of potatoes.

The most important problem with sago as a staple food is the low protein content of the starch, but this is often compensated for by encouraging edible grubs to breed on the bark. The sago can, even though it grows in freshwater swamps, also tolerate considerable amounts of salinity. There are, at the moment, about two million hectares of wild sago stands, besides which about 200,000 hectares of plantations have been established in Malaysia for the production of starch. It has been estimated that the sago stands account for 1.5 per cent of the world's starch production. This may sound little, but it is quite impressive when the rather small area covered by sagos is taken into account.

There is also one South American palm species that resembles sago in many ways: the moriche palm (*Mauritia flexulosa*). The



moriche dominates the freshwater swamps throughout northern South America. Like sago, the trunks of moriche palms are filled with edible starch. Moriche palms, however, grow much larger than sagos, and can actually be rather big and handsome trees.

Species like the nipa palm (growing in saltwater swamps), the sago and the moriche (growing in freshwater swamps) could make an important contribution to the efforts to prevent global warming by offering an alternative to the draining of peatlands. For example, the Indonesian peatlands often contain, on one hectare, almost 100 times more carbon than the rainforests surrounding them. When a peatland area is ditched and transformed into agricultural land, peat reserves start to decompose, releasing huge amounts of carbon dioxide into the atmosphere. According to studies done in Indonesia, draining of tropical peatlands for agriculture can annually release up to 30 tonnes of carbon per hectare.

In spite of the obvious importance of wild palm trees and palm forests, very little research has been done in this area. According to the agroforestry researcher, Anthony B. Anderson:

> Despite the present and potential importance of native palm forests, surprisingly little is known about them. Few published reviews of knowledge concerning these forests exist even on a regional level ... Although ecological studies of locally abundant palms are increasing, almost nothing has been published concerning their management. Why are these economically and ecologically important resources so neglected? In my opinion, one of the chief reasons is that the study of native palm forests lies outside traditional research domains. Many foresters have traditionally focused their attention on wood production, whereas agronomists are trained to work with cultivated crops... As a result, the study of native palm forests has largely been left to economic botanists, whose publications have apparently been ignored by scientists in other fields.

Non-governmental organizations, schools, forest and agricultural extension workers and other amateur scientists should perhaps pay specific attention to the palm trees.

## The Walnut Family (Juglandaceae)

The walnut family includes two important genera of trees: the walnuts (*Juglans* spp) and the hickories or pecans (*Carya* spp). At least 18 species of walnuts and about 20 species of hickories are cultivated for their edible nuts. Walnuts are a rather cosmopolitan genus: four of the species come from South America (Argentinian, Bolivian, Equadorian and Colombian walnuts), two from Central America (Cuban and Guatemalan walnuts), four from Asia (Cathay, Manchurian, Japanese and Persian walnuts) and 10 from North America.

The hickories, on the contrary, have their origin in only two regions: North America and China-Vietnam. The Latin name of the walnut genus means 'Jupiter's acorn'. Jupiter was the supreme god of the Romans, and it is easy to understand why the Romans wanted to link his name with the walnut tree.

Walnuts can become very large and handsome trees. The largest Persian walnut (*Juglans regia*) trees in the state of Jammu and Kashmir in India have reached a height of 45 metres. Some of these ancient plants have attained girths of up to 11 metres. Black walnuts (*J. nigra*) can grow beyond 50 metres in their home region in North America.

Selected cultivars of Persian walnuts have often produced hectare yields between 25 and 40 tonnes per hectare under intense cultivation in Central Europe and North America. The art of walnut cultivation is also rather well developed in Pakistan. In 1973, there were about 800 hectares of land under walnut in the country, and the production was 12,000 tonnes, or 15 tonnes per hectare. However, the annual per hectare production of the mature stands was considerably larger, because a large part of the walnut growing area consisted of immature trees which had not yet reached the productive age.

The weight of the edible kernel of *J. regia* is usually 50–60 per cent of the weight of the fruit—other walnut species have a somewhat less favourable ratio between the edible and non-edible portions of the fruit. The calorific value of the kernel is very high (2,800 kJ/100 g). Of the dry weight of the kernel, 16 per cent is protein, 16 per cent carbohydrates and 64 per cent fat. In other words, the maximum recorded walnut crop of 40 tonnes per hectare is equivalent to a rice crop of 48 tonnes or to a potato crop of 210 tonnes, in terms of calories fit for human consumption. In terms of proteins, the comparison is even more favourable to walnuts.



It must be mentioned that in 1991 the average yield of walnuts in India was still below one metric tonne per hectare. One reason for the low productivity is obviously the large proportion of younger trees which are not yet producing good nut crops. Another reason is that many farmers have probably planted only a few dozen trees per hectare and grow other crops between the nut trees. Many of the walnut plantations have probably been established on soils whose fertility and nutrient content have been depleted by erosion and by the leaching of the nutrients into deeper soil layers. There are probably a lot of trees that are not very productive because of genetic reasons.

Also, the maximum yields mentioned above can only be achieved if some organic or chemical fertilizers are used.

Because walnuts can produce enormous amounts of nutritious food and become very large, they are among the most promising carbon storage trees in the temperate and northern areas. They cannot tolerate very high tropical temperatures, but can be grown in India, Pakistan and Nepal, in areas situated above the altitude of 1,200 metres. Individual *J. regia* trees growing in Himalayas, Tibet, Kirgizstan and Kazakstan have probably survived temperatures below –45 degrees Celsius, so there should be a lot of scope for expanding their range in northern and mountainous areas.

The hickory-nuts or pecans are another important genus of nut trees, with major potential in temperate and northern regions of the world. The commercial pecan-nuts are produced by the species *Carya illinoensis*, which is a native of Mexico and Southern USA. According to J. Sholto Douglas, the largest annual hectare yields recorded in the USA, based on intensive cultivation of selected varieties, have been around 25 tonnes. In India, where the cultivation of pecans is still very young, 2,500 kilograms per hectare is usually considered a good yield. There is, however, a lot of room for improving this. The best trees in India are producing more than 150 kilograms of nuts, with a density of 100 trees per hectare. Hickory-nuts are even

fattier than the brazil-nuts: dry nuts contain 9.4 per cent protein, 15 per cent carbohydrates and 71 per cent fat.

### The Hazel Family (Corylaceae)

Hazels (*Corylus* spp) are another important genus of nut trees. There are more than 10 species producing edible nuts.

Some only become small, bushy trees. Others, like the Turkish (*Corylus colurna*) or Chinese (*C. chinensis*) hazels can reach a height of 35 metres.

According to John Sholto Douglas, improved varieties of the commercially cultivated hazel (*C. maxima*) have been reported to yield up to 30 tonnes of nut per hectare in intensive cultivation in Europe. In India, a typical yield has been around one to three tonnes. The nutritive value of the nuts is high. They contain 18 per cent protein, seven to eight per cent starch and 60–65 per cent fat.

### The Pea Family (Leguminosae)

Leguminosae, the pod-bearing family, includes 17,000 species, most of which are different leguminous trees. All the species have two things in common. First, the fruit is always a one-chambered pod. Second, the root nodules of the leguminosae contain bacteria which have an ability to take up nitrogen from the air. Because of this rare capability of fixing atmospheric nitrogen, the members of the family do not need nitrogen fertilizers but can, in fact, fertilize other crops growing near them. For the same reason, their pods are often a very good source of protein for humans and domestic (or wild) animals.

Leguminous trees have a lot of potential to improve human nutrition. Their most important use may be the production of protein-rich flour that can be used as it is or mixed with maize or wheat flour, and used to make different kinds of breads, porridge, biscuits, macaroni or other types of food. The protein content, calorific value and popularity of the pod flour can be increased by removing part of the fibres through a sieve with a suitable eye-size. Another option is to do some selective breeding: to look for individual trees that produce especially palatable pods and to use them as breeding material.



From the viewpoint of carbon storage forestry, the most important thing would be to look for species that grow to a large size and produce large quantities of palatable pods. The family does include a number of trees that attain a substantial size. For example, the so-called Indian ash (*Acrocarpus fraxinifolius*) typically reaches heights beyond 60 metres, and some leguminous trees growing in the rainforests can become even taller. However, none of the leguminous trees has received much research attention as a potential food crop.

The mesquites or algarobas (*Prosopis* spp) have probably been studied more than any other genus of leguminous trees. Many South American countries are interested in their potential as fodder crops. More recently, the food industries in the USA and a number of other countries have also become involved with prosopis research.

There are at least 40 species of prosopis, many of which produce edible pods. The range of the different algaroba species is very wide. They grow in the drier parts of southern USA and Mexico, in the semi-arid savannah, cerrados and caatingas of Brazil, at the edges of the desert on the west coast of South America, on the lower slopes of the Andes and in many parts of the grasslands of Argentina, in the pampas and in Patagonia. Algarobas are, in vast areas, the dominant tree species. The genus thrives especially in arid, semi-arid or sub-humid land. Before the arrival of the Spanish invaders, algaroba pods formed an important part of the diets of the Aztecs, Incas and numerous other indigenous peoples.

In Brazil, algarobas form an important part of the natural vegetation in an area that covers approximately 50 million hectares. According to Antonio De Oliveira, prosopis stands can, in the semi-arid northeast areas of Brazil, produce an average annual crop of 5,000 kilograms of pods per hectare without irrigation or chemical fertilizers. Cattle-raising can annually produce between 2.6 and 3.6 kilograms of meat per hectare in the same region. Because the protein content of the algaroba pods is comparable to that of meat, the comparison is striking. In terms of human nutrition, algarobas can produce approximately 2,000 times more food than cattle-raising—on an ecologically sustainable basis.

In intensive cultivation the yields can be much higher. In Hawaii, intensively cultivated prosopis plantations can annually produce about 50 tonnes of pods per hectare. However, to achieve such yields, some selective breeding has to be done, and the plantations have to be irrigated and fertilized.

The food industry has started to utilize prosopis pods in the USA, Argentina and a number of other Latin American countries. When the pods are dried so that they contain only five per cent or less moisture, they can easily be milled by hammer mills, pin mills, store mills, or even by hand-used grinding devices in individual households.

The fibre content of the prosopis pods is quite high, so the flour made of them will be more useful if low-cost means for concentrating the protein and for decreasing the fibre content can be found. Researchers have found out that when the pods are ground from one to four times, and when the resulting material is sorted by sieves with different eye-sizes, the protein becomes concentrated in a certain fraction and there is a substantial reduction in fibre content. (In the mentioned study, the researchers used +45, +100 and −100 mesh fractions, and most of the protein became concentrated in the −100 mesh fraction.)

This kind of protein-rich prosopis flour is being used in a growing variety of food products. According to consumer studies, prosopis flour can be mixed half-and-half with wheat flour and used to make bread and cookies without a significant change in taste, colour, structure or other qualities of the final product.

It would almost certainly be possible to also manufacture protein-rich food flours from the pods of numerous other leguminous trees growing in various Asian, European and African countries.

In the Republic of South Africa, the pods of the monkey-bread tree (*Bauhinia thonningii*) have traditionally been used as a famine food by many tribes. They have also been ground into a flour that has been used as a substitute for maize flour.

In terms of calories and protein, the bauhinia meal is almost as nutritious as the maize flour.

*Acacia tortilis*, or the umbrella acacia, is one of the most widespread trees of Africa, and one of the most potent symbols of the



## Why the Banana Tree is Short-lived

Mango, Tamarind, Plantain, Fig and Black Plum were five dancing sisters who decided to get married. They went from village to village looking for husbands, but no one would marry them. The god, Ispur Mahaprabhu, thought: 'If I leave these sisters unmarried, it will be a sin.'

So he asked the five sisters what they wanted. Four of them said together: 'We want husbands and many, many children.' But pretty Plantain said: 'I don't want a husband at all. As for children, not very many, for then I shall lose my looks and grow old soon.'

The four girls were given husbands. The Plantain, only children. Soon they had as many children as the hair on their heads. The husbands took fright at their large families and ran away. But their children caught them and would not let them go. In desperation, the sisters prayed to Mahaprabhu: 'Help us or we shall be destroyed by our children.'

Mahaprabhu turned the girls into trees. Their hair became branches and the children fruit. 'What will you do for husbands?' asked Mahaprabhu.

'Anyone who climbs our branches will be our husband,' replied four of the sisters. So men became the husbands of these trees. But the Plantain refused a husband and, because men keep the trees young with their love, the Plantain has only a few children and matures in one year.

*—A Gadaba tribal legend*

whole continent. It is one of the most drought-resistant trees in Africa, and it can produce large crops of very nutritious pods even during drought years. Besides this, the species produces very valuable and hard timber and is a very effective nitrogen-fixing and soil-improving tree.

According to some sources, *A. tortilis* can survive with 40 millimetres of rain, and in Sahel and Sudan it is usually the tree that extends the furthest into the desert. When there is more rain, it grows better and produces more pods. The pods contain 19 per cent protein, between two and three per cent fat and about 45 per cent carbohydrates. The seeds that form 40–45 per cent of the weight of the whole fruit, contain between 27 and 38 per cent protein. Large trees have been reported to produce more than 200 kilograms of pods per year. *A. tortilis* has a very strong tap root that can penetrate down to a depth of 35 metres.

Besides the umbrella acacia, there are about 1,250 other acacia species. Many of these species, possibly most of them, produce seeds and pods that could be used in the manufacture of edible flour. Of the species, 840 have their origins in Australia, 230 in the Americas, 135 in Africa and 18 in India.

Australian scientists have done some work to develop new food plants from the Australian acacias, also known as wattles. They have tried to combine the traditional knowledge of the continent's indigenous peoples with modern scientific methods of selection and improvement. They started with identifying the potentially most important species with the help of the aborigines, and moved to identification of individual trees that produce pods or seeds that are best suited for human consumption. Promising species that have traditionally been used as food by the aborigines are, for instance, *A. aneura*, *A. cibaria*, *A. longifolia* and *A. oswaldi*.

Tamarinds (*Tamarindus indica*) are large trees that can grow to a height of 30 metres and can be almost three metres in diameter. The tree probably has its origins in the drier parts of Africa, but is now grown all over Africa and India. The tamarind has a very high adaptability, and grows well in both dry and wet climates. It tolerates severe drought. The name tamarind comes from the Persian word *Tamar-i-Hind* or 'Date of India'. The Sanskrit word *amlika*



means 'sour taste'. Common folklore has it that the tamarind tree is the home of spirits that do not let anything under the tree survive. Accordingly, travellers are advised not to sleep in its shade. The most famous tamarind tree in India is in Gwalior, where it stands over the tomb of Emperor Akbar's musician, Tansen. The legend goes that all classical singers should eat some leaves of this tree to make their voices as sweet as Tansen's.

The tamarind is a large, handsome, evergreen tree with spreading branches. The trunk is thick and short and the bark rough, almost black, and covered with long cracks. The fruits hang like long, thick, curved green beans and turn rust-coloured as they ripen. The seeds are dark brown and squarish. The pulp of the fruit has a pleasant, tart taste and is used in curries and chutneys. It is also used to polish brass. The seeds are boiled and ground and used by the tribals as flour. The wood is used for agricultural implements and the leaves make a pretty yellow dye used on silk. Most parts of the tree are used in medicinal tonics. In World War II, it was a major fuel for the gasogen units that powered Indian trucks.

In Tamil Nadu, where the planting density of tamarinds usually varies from 100 to 150 trees per hectare, mature trees usually produce between 100 and 500 kilograms of pods per year. The edible part forms roughly half of the weight of the pods. The pod yield is, therefore, rather large, but there is some cyclicity in it: there is a bumper yield every third year. Pods are highly nutritious, containing about 1100 kJ energy for 100 g of pulp. Tamarind trees can continue producing good crops for 200 years or more. Fruit flesh can be eaten fresh or preserved in syrup. The seeds are eaten as nuts. Tamarinds are also used as a condiment and in flavouring.

So far, researchers have not developed improved varieties of tamarinds. However, it has been reported that the Tamil Nadu farmers usually identify mother trees that constantly produce large fruit crops, and grow new tamarind seedlings from the seeds of such superior trees. During the centuries, such practices have probably amounted to a kind of collective breeding effort. In the Dharmapuri district of Tamil Nadu, there is one tree which produces pods 25 centimetres long and five centimetres wide. The specimen might well be a result of the work of several generations of amateur tree breeders.

The flour made of the pods and seeds of leguminous trees is likely to have the largest significance in dry areas. However, the same methods could also be used in various rainforest areas.

In humid Asia and Africa, special attention should perhaps be paid to the so-called African locust beans (*Parkia* spp).

Members of the genus can be found in relatively moist areas of South and Southeast Asia and Africa. Many species (for example, *P. africana*, *P. speciosa*, *P. roxburghii*, *P. piglandulosa* and *P. filicoidea*) produce edible pods or seeds. The fruits of the parkia species are often called nittanuts or African locust beans. According to J. Sholto Douglas, the plantations in Malaysia have reached annual hectare yields of 25 to 40 tonnes.

In the rainforests of Central and South America, there are a huge number of leguminous trees that could be developed as food crops for humans. In the Brazilian Amazonas alone, about 1,000 leguminous tree species have already been identified. Two of them belong to the emergent class, to the giants of the rainforest trees: angelim (*Dinizia excelsa*) and cedro rana (*Cedrelinga catenaeformis*). Also, in the Indonesian rainforests, leguminous trees dominate the highest (emergent) layer of the forest together with the members of the dipterocarp family. The tallest of all Indonesian rainforest trees is a leguminous tree called sialand (*Koompassia excelsa*), that can reach a height of 70 or 80 metres.

Inga (*Inga* spp) is an American genus of trees, several species of which are grown in Central and South America because of their fleshy, edible pods. Some species have adapted to dry conditions and thrive on the arid lands of Mexico, others require high rainfall. Perhaps the most important species in the genus is the food inga (*I. edulis*), which produces large amounts of large and very palatable pods.

In Yurimaguas, in the Peruvian Amazonas, agroforestry researchers have been developing a multi-strata agroforestry system in which *I. edulis* and the peach palm are the most important crops. According to the studies, such a multi-storey system is, in financial terms, approximately 80 times more productive than shifting cultivation. The difference with cattle-raising is even more striking.



Some leguminous trees could also become important sources for vegetable oils. The African oil bean or atta bean tree (*Pentaclethra macrophylla*) growing from Senegal to Angola is a good example. According to Edward Menninger, the tree bears large pods 45 centimeters long and 10 centimeters wide. The beans are known as oil seeds, and the oil yield is 30–36 per cent of the weight of the seeds.

Some members of the family could probably be introduced and domesticated in colder areas far up in the north or high on the mountains. The most promising genus for this purpose could be the so-called honey locusts (*Gleditsia* spp). The most important species are the American honey locust (*G. tricanthos*) and the Japanese honey locust (*G. japonica*).

The American honey locust has a wide range from Ontario (Canada) down to Texas. The species has also been introduced to a number of African and European countries. The American honey locust is an attractive, relatively large tree that can reach a height of 45 metres. The wood is strong, durable and valuable. Pods are large, between 30 and 45 centimetres long. They contain a sweet succulent pulp which has a 27 per cent sugar content when fresh and 60 per cent when dried. Pods are usually fed to animals, but they can also be eaten by humans. They can be ground into nutritious flour, even though this is no longer widely practised.

North American monocultures growing grafted superior specimens can annually produce between 35 and 50 tons of pods per hectare. Best trees yield up to 500 kilograms of pods in one fruiting season. Production is regular and reliable, and the pods are easy to harvest. Besides sugar, the dried pods contain 16 per cent protein and eight per cent fat.

Honey locust has a relatively open top foliage, which makes it possible to grow other crops which tolerate some shade, between the trees. The non-improved varieties can be propagated from seed and the improved varieties from root-suckers. Some strains thrive well in areas where the average annual minimum temperatures range between –35 and –39 degrees Celsius. In time it should be possible to adapt the species to tolerate even colder temperatures. During the next Ice Age, honey locusts might well become one of the most important sources of bread and porridge flour for humanity. Even

before this, they might become useful in improving food security in northern areas and high mountains.

## The Olive Family (Oleaceae)

The olive family includes a total of 500 species, most of which grow in the northern hemisphere. The most important genera in the family are the ashes (*Fraxinus* spp) and the olives (*Olea* spp). In this book, we will only deal with the olive trees.

The European olive tree (*Olea europeae*) is one of the most important oil-producing trees in the world. Olive trees have been grown for at least 6, 000 years, and possibly for 11, 000 years, first in Lebanon, Syria, Jordan, Turkey, Iraq and Israel, and later in the North African and southern European countries, on the islands of the Mediterranean, in Iran, Pakistan and Afghanistan. During the last few decades, the growing of olives has also spread to India, Australia, USA, China and South Africa.

Olive oil was the most valued commodity in the ancient Mediterranean world (southern Europe, North Africa and the Middle East) and the backbone of its economy. Ancient Phoenicians, Greeks and Romans considered olive oil the elixir of the gods. In the holy book of the Christians and Jews, the Bible, olive is the most important and sacred of all trees. In the Arab world, it shares this honour with the date palm.

The world currently produces more than three million tonnes of olive oil in a year, which is equivalent to about 15 million tonnes of olives. Best groves have annually yielded from eight to 10 tonnes of olives per hectare. However, scientists working in Israel have recently developed astonishingly productive varieties of olive trees, which give still much higher hectare yields. Most of the world's olive crop is consumed in the Mediterranean region by somewhat more than 100 million people, for whom olive oil is an indispensable part of the daily diet. However, olive oil is rapidly becoming more popular elsewhere in Europe and in the USA. The US imports of olive oil increased by 500 per cent in 15 years (1983–1998), from 50,000 tonnes to 250,000 tonnes.

The reason is simple: olive oil is one of the healthiest known vegetable oils. Most oils and fats that are used in cooking contribute



to the development of cardiovascular diseases—they contain fats that can, in the long run, block the arteries in the heart, brain or limbs. Olive oil seems to have the opposite effect—instead of causing cardiovascular disease, it actually contributes to the prevention of such illness. Up to 80 per cent of olive oil is made of fatty acids which are efficient in keeping the 'good' cholesterol levels up and 'bad' cholesterol down. Only 4–12 per cent consists of the harmful fats, so the balance is very positive. The impact is complemented by the high polyphenol and vitamin E content. Because of the high consumption of olive oil, cardiac heart disease is four times less common in Greece and Italy than in the United States of America or Great Britain.

Cardiovascular diseases are already responsible for roughly one-third of the global mortality among the human population. At least half of these deaths are premature, and could have been prevented by healthier diets. The situation is likely to get worse in the future. The World Health Organization estimates that the annual mortality caused by cardiovascular disease in the Asian, African and Latin American countries could exceed 14 million by the year 2020. Such an epidemic of cardiovascular disease could divert much of the resources of the health care systems away from meeting the needs of the poorer segments of the population. The large-scale production of healthier cooking oils and dietary fats—from olives and other trees producing healthy food oils—could prevent most of the premature deaths and illness caused by cardiovascular disease.

Besides resisting the clogging of the arteries, olive oil also seems to reduce the risk of some cancers. An important study showed that women who eat olive oil more than once a day have a 45 per cent reduced risk of developing breast cancer. Olive oil may also help to prevent peptic ulcers and gallstones. According to some studies, foods fried in olive oil maintain more of their nutritional value than those fried in other types of oils. Olive oil is a very efficient preservative, and it can be mixed with lime and water to treat burns.

The European olive has a vast range, starting from the Mediterranean and stretching through Africa to the southernmost part of the continent. The species should actually be called the African and not the European olive, because most of its range is in Africa. How-

ever, there are also a number of other African species that produce edible fruit and that do not grow in Europe or in the Middle East.

European olive trees can live for 1,500 or 2,000 years and the old trees can be very impressive. Their trunks and branches become fantastically gnarled, which makes them unmistakable from other trees. They never become very big, and seldom grow taller than 15 metres. Some of the African olive trees, like East African olive (*Olea hochstetteri*) or Elgon olive (*O. welwitschii*) can be substantially larger, and reach a height of 30 metres.

The presently cultivated commercial Mediterranean olive varieties require relatively low winter temperatures. They can be cultivated in South Asia on somewhat higher grounds. The African subspecies of the same species (*O. europaea* subs africana) and the other African species could be grown even in tropical and subtropical lowlands. It would probably be a good idea to carry out some selective tree-breeding efforts with these species to increase the size of the fruits and to improve the quality of the oil. Such a domestication and breeding programme might, in the long run, have a major beneficial impact on public health all over the world.

Olive trees already have a magnificent history, but their most golden days may still lie in the future. From the public health, ecological and economic viewpoints, it would make perfect sense to replace—in every country—most of the dangerous food oils with healthier oils during the next 100 years or so. This could be done by domesticating the wild African olive species, by spreading the cultivation of the Mediterranean olives to the temperate zones of Asia, and by developing other healthy food oils from the seeds and fruits of beneficial edible oil trees. People will be able to live longer lives in better health if everybody has, in the future, access to cheap healthy oils and the benefits that are now enjoyed by the Mediterranean peoples.

### The Mango Family (Anacardiaceae)

The mango family includes about 600, mostly tropical, tree species. In this context, we will only mention two of them: the mango (*Magnifera indica*) and marula (*Sclerocarya caffra*).

The mango tree is known mainly for its fruit, which is rich in vitamins. Preserves and pickles are made from the unripe fruit, and



its pulp is dried and used as a curry base. The wood is used for packing cases. The gum of the bark, the seeds which contain gallic acid and the astringent leaves are used in medicines.

The largest mango tree in the world grows in a village called Burail in Ambala, India. It has been given the name of *chhappar*, or roof thatch, probably because it gives shade to so many. The area covered by the crown is 2,700 square yards and its average yearly yield is reported to be around two tonnes.

The word mango probably comes from the Tamil word *mangas*, or the Malayan word *mangga*, or the Portuguese word, *manga*. *Mangifera indica* means 'the Indian mango-bearing tree'. The Sanskrit word for mango, *amra*, also means a particular weight.

The mango probably has is origins in the area including India, Bangladesh and Burma. It has been cultivated in India for more than 4,000 and possibly for 6,000 years. It was found by Alexander's army when it entered the Indus Valley in 327 BC. Representations of it are found on the Stupa of Barhut and Sanchi dated 150 BC. Arab traders introduced the fruit to the eastern coast of Africa in the fourteenth century, and since then it has spread throughout the African continent. It is also cultivated in most Southeast Asian and Latin American countries. In Punjab (India) there are mango trees that are more than 500 years old and which are still producing good fruit crops.

In many African countries, mango has a lot of nutritive importance. Its significance is largely based on the fact that it produces large crops of nutritious fruit in the very beginning of the rainy season, at the time when the food reserves of the rural households have reached their annual bottom line. The calorific value of the fruit flesh is only slightly less than that of the potato, and it also contains some protein. Mango fruits are rich in vitamin A and C, which adds to their significance for people's health.

On the African continent, there are now large areas from which all or almost all other trees except mangoes have been felled. In some areas such 'mango savannah'—agricultural lands dotted with mangoes—can continue for tens or even hundreds of kilometres almost without interruption.

In Hindu-Buddhist mythology, mango is one of the most sacred trees. It is symbolized in Hindu mythology as a wish-granting tree and as a symbol of love and devotion. It is supposed to be an incarnation of Prajapati, the Lord of all creatures. Its flowers are dedicated to the moon.

Many indigenous peoples of South Asia practice symbolic marriages with trees. In such ceremonies, the bridegroom is often married to a mango, and the bride either to a mahua (*Madhuca indica*) or to another mango tree. The bride and bridegroom walk several times round the mango tree before the actual ceremony of marriage takes place. The groom smears the mango bark with vermillion and embraces it. The bride does the same thing to the mahua tree. After the ceremony, the couple will always be married, as long as their trees are still living, even if one or the other or both were to die prematurely.

Other legends say that the mango tree was brought from Lanka to India by Hanuman. Hanuman, taking a message from Rama to Sita, leapt from tree to tree. Resting for a while on the mango tree, he was so delighted with the flavour of its fruit, that he threw the seeds into the sea and they floated across to India and took root.

It is believed that Shiva married Parvati under a mango tree. So marriage pandals are festooned with strings of mango leaves. The wood is used in funeral pyres. Village superstition has it that at every birth, the mango tree sprouts new leaves, and so mango leaf garlands are hung over the door of the house where a son has been born.

Spirits of dead ancestors are supposed to live in mango trees. Baji Rao's ancestors had murdered the Maratha Peshwa, Narayan Rao, in 1772 and taken his throne. Baji Rao believed himself to be haunted by the spirit of Narayan Rao. He ordered several thousand mango trees planted around Poona to shelter the angry spirit.

Marula (*Sclerocarya caffra*) is one of the wild African relatives of the mango. It could become one of the most important carbon storage trees in the world, because it can produce huge quantities of nutritious fruit and nuts in very dry conditions.

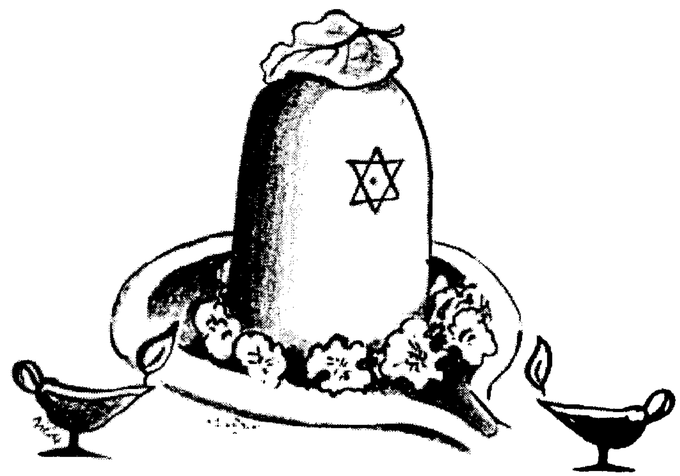
The range of marula is huge, and covers more than half of sub-Saharan Africa. It is also a native of the Kalahari and the Namib



## The Hunter's Worship

A hunter lived in Varanasi. He was not religious — in fact, he did not believe in going to temples or in observing any rituals to please the gods.

One day, he went hunting in the forest. He chased a deer deep into the forest but he could not kill it. By the time he gave up the chase it was night, and he was too tired to find his way back. So he climbed a bael tree and started breaking the leaves to make a soft perch so that he could spend the night comfortably.



A small Shiva temple had been made at the base of the tree trunk and as the hunter plucked the leaves, a few of them fell on the Shivalinga. The hunter perspired from his efforts and a drop of his sweat fell on the Shivalinga too. He had not eaten at all that day for he had been hunting game since dawn. So you could say the hunter had been fasting. And the day was the fourteenth day on the dark phase of the Moon in the month of Phalguna (mid-February to mid-March), a day sacred to Shiva.

The hunter had, without knowing, fulfilled all the conditions for the worship of Shiva. This pleased the god so much that when the hunter died he went, in spite of being an unbeliever, straight to heaven.

*—From Kathasaritsagara*

deserts, the oldest deserts in the world. These southern African deserts have probably existed for at least 80 million years. The plants and trees growing in and around them have had more time to adapt themselves to dry conditions than plant life in any other region of the world. For this reason, the area has produced a dazzling array of food-producing trees that can thrive in extremely dry conditions.

The average annual production of the mature, randomly selected marula trees is about 500 kilograms per tree even in Botswana, which is a very dry country. Individual specimens can produce far larger crops. Marula fruit contain extremely nutritious, edible kernels which are about the size of a small hazelnut, and which are usually eaten by children, who require the protein for their growth. In the villages which have at least some large marula trees, they seem to have a very beneficial impact on the children's nutritional status and health. The nuts contain 55 per cent oil, of which 70 per cent is oleic acid and eight per cent linoleic acid. This means that marula oil should definitely be one of the healthiest known food oils. The fruit flesh contains four times more vitamin C than oranges.

However, the wild marula fruit are very small. Their average weight is only 18 grams. Because the fruit are so small, it requires a big effort to use them as food. Moreover, according to a study made by the Veld Products Research and Development (VPRD) in Botswana an average of only 6.47 per cent of the weight of the fruit consists of the edible fruit flesh and about three per cent of the edible kernels. In other words, the ratio of the edible and non-edible parts of the fruit is rather unfavourable: more than 90 per cent of the fruit consists of the inedible peel and of the nutshell.

Therefore, wild marula fruit has mostly been used to produce vitamin-rich fruit juices or alcoholic drinks (because the fruit juice is rich in sugar). Besides this, a very healthy oil can be extracted from the nuts, but this requires a lot of work, because the fruit are so small.

A project of the VPRD and Coalition for Environment and Development has been looking for wild varieties that produce larger fruit. The best varieties that have been identified by the VPRD are producing fruit with a weight from 70 to 100 grams. The fruit produced by these superior trees are already so large, that the percentage of the edible parts is more than 50 per cent—six times more than the average for wild fruit. The final aim is to breed even better varieties, but this takes a lot of time, because the male and female flowers are in separate trees.



VPRD is also implementing a trial in which selected marula trees are grown with a 10 x 15 metre spacing, 60 trees per hectare. According to observations made in the wild, the trees should be able to produce the typical annual fruit crop of 500 kilograms of fruit per tree with this kind of spacing. If the trial confirms this assumption, the results may amount to a middle-sized revolution in dryland agriculture.

Mature marula trees typically become 15–20 metres tall and grow relatively thick trunks. However, they usually remain somewhat smaller than the mongongo trees.

### The Euphorbia Family (Euphorbiaceae)

The large and very diversified *Euphorbia* family includes more than 5,000 trees, shrubs and herbs. However, in this context the family is mentioned mostly because it includes one of the future superstars of arid land agriculture: the mongongo nut tree (*Schinziophyton rautanenii*).

The mongongo is, after the baobab, the second largest tree that can survive and thrive in the drier areas of Africa. It can reach a height of 20 metres or more and attain a diameter of two metres.

Mongongo grows wild in the sandy soils of the semi-arid parts of southern Africa. According to an old legend, bushmen never developed agriculture, because there were so many mongongo nuts in the world. During our time, however, the mongongo trees have become a rarity in some countries, which is a good argument in support of the domestication of this important species.

The fruit of the tree has a thin, edible, fleshy part, which is an excellent source of minerals, and contains about the same proportion of protein and vitamins B as wheat or other cereals. Mongongo also has one of the richest oilseeds in the world: the pleasant-tasting kernels are the size of hazelnuts, and contain 57–63 per cent edible oil. They also have a very high protein content, and their calorific value is twice as high as that of rice. The oilcake has over 60 per cent

protein, which is more than in cottonseed, groundnut or soya beans. The oil contains 18 per cent oleic and 42 per cent linoleic acid, which means that it is healthy, although probably somewhat less beneficial for the arteries than marula or olive oil.

According to an old study by the anthropologist R.B. Lee, mature mongongo trees yield between 20,000 and 60,000 fruits per year. The average weight of the fruit is about 10 grams, which makes an annual crop of between 200 and 600 kilograms per tree. The identification and cross-breeding of superior specimens might result in even higher yields and in increased fruit size. It might also be possible to increase the portion of the edible parts of the fruit. In wild fruit, on average only 27 per cent of the weight consists of the edible fruit flesh and nine per cent of the kernels. In other words, the non-edible parts form 64 per cent of the fruit.

Breeding efforts, however, are hampered by the fact that mongongo is a dioecious tree: male and female flowers grow in different trees. This makes breeding more difficult, because it takes a lot of time to identify superior male trees that will influence the quality of the fruit in the desired way.

Cassava (*Manihot esculenta*) belongs to the same family of plants. It is not a tree, but a bush with a woody stem and with a relatively deep root system. Cassava is resistant to drought and grows well in dry areas and poor soils on which annual plants can hardly be cultivated. On a per hectare basis, it can produce two or three times more calories than maize. Cassava is also a very flexible crop in terms of planting and harvesting dates: the roots usually mature in 12 months, but they can be left in the ground for two years. This has made it a very important safety net crop for numerous rural families.

Cassava roots may have been the first staple food of the South American farmers. It seems likely that the plant was cultivated in Peru some 4,000 years ago. In terms of calories and carbohydrates for human consumption, cassava is the third or fourth most important crop in the world. The leaves are edible, too. They have a high protein and vitamin A content, and they have a very beneficial effect on the health and nutritional status of children, when mixed with different foods.



In spite of the fact that cassava is the staple food for more than 300 million people, it was almost totally neglected in agricultural research until the late 1970s. In the early 1980s the annual yields of cassava in West Africa averaged 6.8 tonnes per hectare. This was much less than in Latin America. The main reason for the low yields were various pests and diseases: cassava mosaic virus, bacterial blight, green spider mite and cassava mealy bug.

The Korean programme manager, Sang Ki Hahn, and his co-researchers working in IITA (International Institute for Tropical Agriculture) in Ibadan, Nigeria, aimed at breeding varieties that are resistant to these diseases and pests and which can do well without chemical fertilizer or pesticides.

Nigeria does not have an agricultural extension service, and officials said that it would take at least 100 years to spread the new varieties to the farmers. They were wrong. It turned out that it would have been very difficult to stop them from spreading.

Sang Ki Hahn started the diffusion of the new varieties by loading cassava plants on a lorry. This way he was able to distribute cassava plants to 1,000 farmers a day. This was not much, because Nigeria has a population of about 120 million. However, when the farmers realized that the new varieties really were resistant to the most important diseases of cassava, and that they gave yields that were 50–100 per cent higher also during the drought years, the new varieties started to spread like wildfire. Farmers started to spread them by giving seedlings to their neighbours and relatives. The new varieties also grew larger and more bushy than the older ones, which reduced erosion. Increased shading also lessened the need for weeding. Yoruba farmers were so grateful to Sang Ki Hahn that they made him honorary chief with the title Seriki Agbe—the King of the Farmers.

## The Ebony Family (Ebenaceae)

The ebony family includes one very important genus (*Diospyros* spp) which produces both the highly valued ebony wood and the American and Asian persimmons. There are, altogether, more than 400 different species of diospyros trees. The American (*D. virginiana*) and Asian (*D. kaki*) persimmons are productive fruit trees that can

annually yield between 12 and 18 tonnes of fruit per hectare in well-cared for plantations. They also produce good-quality timber. Many wild diospyros species also produce edible fruit, but they are much smaller than the actual, domesticated persimmons. In Africa the most important product of the diospyros trees has always been tropical hardwood.

In ancient times, ebony used to be the most valuable export product of Africa, together with ivory. The real black ebony comes from two diospyros species (*D. ebeneum* and *D. reticulata*) that occur mostly in the upper Nile region, but many other species also produce highly priced hardwood timber. The most important timber species have become sadly rare because of their commercial utilization.

From the viewpoint of less well off families, the species that can both produce valuable timber and large crops of nutritious fruits are clearly the most interesting. Such trees could become a kind of bank or monetary deposit for the poor households and increase their economic security in a very significant way. Families could grow a number of diospyros trees and sell one or two for timber, when in desperate need of money either due to illness, famine or any accident. In such situations, the options available for a small farmer are often very limited. In most cases, the farmer has to sell part of his land. To sell some valuable hardwood, planted as an insurance, would definitely be a much more desirable alternative.

One of the truly interesting species is the African ebony or the jackalberry (*D. mespiliformis*). It is one of the most handsome trees growing in southern Africa. It can reach a height of 25–30 metres and a diameter of 1.5 metres. The wood is hard and valuable, with a dry weight of 0.85. The fruits are about 2.5 centimeters in diameter, and very popular among the local people.

The closely related species (*D. melanoxylon*) known as Coromandel ebony in English, *tendu* in Hindi and *dirghapatraka* in Sanskrit has major economic importance in South Asia, both because of its edible fruit and especially because its leaves are used to make *bidis*, the local cigarettes. This use, of course, is a mixed blessing, because smoking is not a very healthy habit.



The size of the fruits and the annual yield of the various wild diospyros trees could probably be improved by selective breeding. It would be important to breed varieties that would both grow a long, straight stem and produce a good fruit crop. Such trees could become a very important form of insurance for the poorer households.

## The Pine Family (Pinaceae)

The pine family consists of conifers mostly growing in northern latitudes. Even though some tropical species also exist, the members of the family only have importance as carbon storage trees in the temperate and northern forest zones, and possibly in some relatively high, mountainous areas.

The pine genus (*Pinus* spp) includes 18 species that produce edible seeds, so called pinions or pine nuts. The pinions have a high nutritive value and contain, on average, 14 per cent protein, 21 per cent carbohydrates and 60 per cent fat.

From the viewpoint of carbon storage forestry and food production, one of the most important species is the cembra pine (*Pinus cembra* subs *sibirica*). Cembra pine does not grow as big as many other pines: the largest trees can become about 40 metres tall, but such heights can only be achieved in the more southern parts of their natural range. However, together with the rowan (*Sorbus aucuparia*) cembra pine is the most important food-producing tree that can survive and produce food in northern Russia and Siberia. The most resistant strains survive temperatures below –70 degrees Celsius without damage.

The Siberian cembra pine must be one of the most numerous food-producing trees in the world. It is one of the four conifer species that dominate the vast Siberian taiga forest that covers about 1,200 million hectares. In much of the taiga, the forest consists almost solely of these four species: the Siberian race of the Norwegian spruce (*Picea abies*), the Siberian larch (*Larix sibirica*), the Siberian fir (*Abies sibirica*) and the Siberian cembra pine. Scots pines (*Pinus sylvestris*) are much less common, and the broad-leaved trees come into the picture only in the southern fringes of the taiga.

People in Siberia have always used the oily seeds of cembra nuts, or pignolias, as famine food. They could have done worse, because the pignolias have a still higher protein content than other pine nuts. Dried pignolias contain 31 per cent protein, 13 per cent carbohydrates and 48 per cent fat. The seeds are large for pine seeds, about one centimetre across.

In the 1860s, the Russian Empire experienced a terrible famine that killed millions of people. For example, Finland, the most western part of the empire, lost 130,000 people out of the population of 700,000. The Czar was very impressed by the fact that practically no one had starved to death in Siberia, where the people knew how to eat pignolias as famine food. In order to prevent new disasters, the Czar ordered his officials to ensure that cembra pines were introduced and planted in sufficient quantities in all parts of his empire.

However, the orders of the Czar were carried out a bit halfheartedly. Not so many cembra pines were planted, and too little attention was paid to where the seeds had been acquired from and where they were then planted. Because of this reason, many cembras became stunted trees that did not grow well and were not so beautiful to look at, and planting them did not become popular throughout the Russian Empire. This was a pity, because large-scale planting of cembra pines outside Siberia might have saved 20 or 30 million people from starving to death during the famines related to the First World War, the Russian Civil War, the forced collectivization of agriculture and the Second World War.

During the next Ice Age, the cembra pine might become an important food-producing species. In any case, it would be interesting to find out whether its food-producing qualities can be improved through selective breeding. There seems to be some variation in the number of cones and seeds produced by different trees of a similar size. Part of this variation may be caused by genetic factors. It would also be interesting to look for individuals that produce larger seeds than the others, even though this would probably require a lot of work. Possible breeding programmes need to have a very long-term perspective, because cembra pines only start to flower and produce seeds after their sixtieth year.



Cembra pines can live up to 600–800 years. It is a slow-growing species, but because of the slow growth, it produces strong, although relatively light timber. The wood of cembra pines was widely used in furniture and carving in many European countries before the Alpine subspecies became so rare that the remaining trees growing in central Europe were protected by law.

The largest of the pines producing edible seeds—and the largest of all pines—is the North American sugar pine (*Pinus lambertiana*), reaching beyond a height of 80 metres. The British naturalist, David Douglas, called the sugar pine 'the most princely of the genus: perhaps even the grandest specimen of vegetation.' This comment is perhaps a bit surprising, because Mr Douglas had seen much higher giant sequoias and Douglas firs.

Hugh Johnson, the author of the famous international encyclopedia of trees, writes about Douglas's comment:

> Having met the grandfather of all sugar pines in a valley in the Siskiyou mountains of Oregon I can only say Amen. The monster stands 270 feet or so, not as a pole with a shaggy top, as western giant trees tend to be, but mightily branched most of the way up; a forester's nightmare. Sugar pine branches are straight, and of immense length...each branch near the top must be 70 feet long, weighed down only slightly with its colossal two-foot cones at the tips.

*P. lambertiana* is a tough candidate for the world's largest food-producing tree, and it might be a good idea to introduce the species to other geographical regions where it can grow well. The writers of this book have not come across any estimates about the annual hectare or per tree yields of pine nuts that could be expected from sugar pine cultivation, and would be most grateful of even anecdotal information concerning this matter.

Among the pines, the ponderosa pine (*P. ponderosa*) takes the second place. The ponderosa can reach a height of 75 metres, and also produces edible seed. The species has a huge natural range that covers more than half of continental USA and a major part of Mexico.

Eastern white pine (*P. strobus*) can become almost 70 metres tall and very thick. In the 1850s, large individuals were so common in

the USA that the foresters considered trees that were less than one metre in diameter too small to be felled. In Europe, the most popular pine nuts come from the pinyon (*P. pinea*), which is a beautiful middle-sized pine not reaching much higher than 30 metres.

The chilgoza pine stands (*P. gerardiana*) in India are said to produce approximately two kilograms of seeds per tree when planted with a density of 400 or 500 trees per hectare. This would amount to roughly one tonne per hectare in a year. Chilgoza, however, is not a large tree. It seldom grows more than 20 metres high, even though the mature trees often have a girth of three or four metres. Also, the seeds are very small: a kilogram means about 4,600 chilgoza seeds.

The pine family includes a number of other species that may have importance as carbon storage trees in northern and temperate areas, even though they do not produce food for human consumption.

Foresters tend to claim that the Norwegian spruce (*Picea abies*) is a short-living species which usually starts to rot before even reaching the age of 100 years. However, in the Carpathian mountains in central Europe, there are stands that are 700 years old. The ancient spruce trees growing in these stands are often 60–65 metres tall and more than one metre thick.

The real giant of the spruce genus is the North American sitka spruce (*P. sitchensis*). Sitka spruce is a very long-living conifer which reaches full biological maturity only at the tender age of 500 years. The largest sitkas can be 90 metres in height and have a diameter of five metres.

The giant fir (*Abies grandis*) can grow 100 metres tall. It is a native of North America, but it has thrived well when planted in Europe. A giant fir that was planted in Scotland raised its crown to a height of 50 metres in 53 years. The Caucasian fir (*A. nordmannia*) and the western hemlock (*Tsuga heterophylla*) can grow to 70 metres.

Some of the members of the larch genus (*Larix* spp) can grow 60 metres tall. In the northern parts of the boreal forest zone—in the northern parts of Scandinavia, Russia, Siberia and Canada and in parts of Alaska—larches probably grow larger and thicker than any other trees. In these areas, they could probably form larger stores of organic carbon than any other tree species.



## Why Brahmins Remain Poor

The bael tree is supposed to be the abode of Lakshmi, the goddess of fortune and consort of Vishnu. In fact, *Bilvapatrika*, 'she who lives in the leaves of the bilva (bael) tree', is another name for Lakshmi.

Lakshmi enters mortal homes and those whom she blesses prosper and are happy. But Lakshmi is supposed never to have entered a Brahmin's house.

'Why?' asked Vishnu of his consort. 'Brahmins keep the temples. They are holy and pious and worship all of us. Why are you so adamant about not blessing them with your luck?'

Lakshmi answered petulantly: 'All Brahmins are my natural enemies. I cannot even rest peacefully in my house, the bael tree, for every day they pluck leaves of it and offer them to Shankara (Shiva). If they destroy my house why should I enter theirs?'

And Vishnu had no answer to this.

The Russian Czar, Peter the Great, ordered his generals to establish larch plantations in order to provide large quantities of high-quality timber for the Russian navy. A Siberian larch (*Larix sibirica*) plantation established in Raivola in 1738 has survived almost intact to our days, even though soldiers during the World Wars cut some of the trees. The best-growing part of the forest now contains 2,000 cubic metres of trunk wood per hectare. Because larches also have a massive, heart-shaped root system, it is likely that this forest contains at least 700 or 800 tonnes of carbon per hectare in the form of wood alone. To this must still be added the carbon stored in the litter and in the humus layer. These are impressive figures, keeping in mind that the Raivola forest grows in the far north, in an area where the tallest trees are less than 45 metres high. Larch timber is especially valuable for underwater structures, because it experiences hardly any rotting under the water. The city of Venice, for example, was originally built on top of larch poles.

The Douglas fir (*Pseudotsuga menziesii*) is one of the real giants of the plant kingdom. It can grow more than 100 metres tall and three and a half metres in diameter. The rapid growth of height continues for at least 200 years, after which the trunk diameter can keep on increasing for hundreds of years. Ancient Douglas fir forests typically contain 2,000 or 3,000 cubic metres of trunk wood per hectare, which is a very high figure for a natural forest.

Such forests should contain very large amounts of carbon. Three thousand cubic metres of trunk wood is equivalent to about 700 tonnes of carbon, to which must be added the carbon stored in the branches, needles, roots, litter and the humus layer. We have not found reliable estimates about the amount of carbon that could be stored in the root system or in the humus layer of the old Douglas fir forests. However, in one study it was estimated that the mere litter in a 450-year-old Douglas fir and hemlock forest contained 125 tonnes of carbon per hectare. With such magnitudes of coarse and fine litter, we can rather safely assume that also the humus layer would contain substantial amounts of carbon.

Well-managed Douglas fir plantations might finally produce even larger storages of carbon, if we let them grow for a long enough time. A 60-year-old Douglas fir plantation typically contains 200



tonnes of carbon per hectare, if only the wood (trunk wood, branches and roots) and not the litter and humus layer are counted. However, it might be possible to grow a Douglas fir forest that would finally contain approximately 400 trees, each of which would contain on average 15 cubic metres of trunk wood.

Also the so-called true cedars (like *Cedrus deodara* and *C. libani*) that have been mentioned in the earlier chapters of this book, belong to the pine family.

## The Cypress Family (Cupressaceae)

The Cypress Family includes a few species that may have importance as carbon storage trees in certain areas, even though they do not produce food that is edible to humans.

A close relative of cypresses, *Fitzroya cupressoides*, is the largest tree growing in Patagonia (the southern part of South America). It often reaches an age of 2,000 years or more, and can be 60 metres tall and five metres in diameter.

The African pencil cedar (*Juniperus procera*) is the largest indigenous conifer growing in the African highlands. It is also the largest member of the juniper genus. African pencil cedars can reach a height of 50 metres, and they produce fine and valuable timber.

The giant arbor-vitae or the western red cedar (*Thuja plicata*) can reach a height of 70 metres and the diameter of the largest specimens can sometimes exceed 10 metres at the ground level.

## The Eucalyptus Family (Myrtaceae)

Guava (*Psidium guajava*) deserves a mention because of its high fruit production. It is not a large tree, seldom reaching a height of 10 metres. But in ideal conditions, it has been recorded to produce an annual crop of 110 tonnes per hectare, and the calorific value of the fruit is equivalent to potatoes. In spite of their relatively small size, the best guava trees have produced more than two tonnes of fruit in a year. The superior specimens can easily be propagated from cuttings or root suckers. Guava spreads easily and effectively, and in many countries it has been proclaimed a weed, in spite of its nutritious fruit.

The eucalyptus genus (*Eucalyptus* spp) includes more than 600 species. The eucalypts are the dominant trees of Australia: on the continent, three-quarters of all forest trees are eucalypts.

Because the eucalypts have adapted themselves to the tremendously variable environmental conditions reigning in different parts of Australia, they have become a very diverse genus of trees.

Eucalypts have a worse reputation among environmentalists and social activists than any other trees. There are good reasons for this. Large eucalyptus plantations producing pulp for paper mills have often replaced diverse natural forests, depriving people of an important source of fuelwood, food, fodder and small timber. In Thailand, the government tried to establish four million hectares of commercial eucalyptus plantations, which would have resulted in the forced dislocation of between five to ten million people. The determined resistance of the local peasant movements, however, halted the plan. In India, eucalyptus plantations have often been established on good farmlands, which has resulted in the loss of about one job for each hectare transformed to a wood plantation. Water-thirsty eucalyptus plantations have often lowered the water table when they have been planted in areas with too little rainfall. Dense planting of wrong eucalyptus species has led to accelerated erosion by the suffocating of the undergrowth. Litter production has not usually been sufficient to prevent the loss of topsoil during the rainy season.

However, this does not mean that the eucalypts are inferior trees. On the contrary: in their native habitats they are wonderful, handsome trees. The world's tallest broad-leaved trees are eucalypts. There are two species that can reach the royal height of 100 metres: the giant eucalyptus (*Eucalyptus regnans*) and karri (*E. diversicolor*). At the beginning of this century, there were reports of eucalypts exceeding 140 or 150 metres in height, but because the trees in question were felled after the measurement, the figures have never been verified. It is a bit difficult to take them seriously, because the largest eucalypts still growing in Tasmania are only slightly more than 100 metres tall.

However, the largest Tasmanian giants are only 400 years old. What if there have really been much older eucalypts that have reached even more prominent heights than the present record-holders? The



famous geographer, Alfred Russel Wallace, once measured a fallen eucalyptus that was 137 metres long. Also, there is an old photograph of a huge eucalyptus stump 8.5 metres in diameter.

Some eucalyptus species are very fast-growing trees. The highest tree in New Zealand is an eucalyptus (*E. regnans*) that was planted in 1878. The height of the tree in 1969—only 90 years after planting—was an impressive 71 metres, and the diameter at shoulder height was almost four metres.

All eucalypts produce an essential oil. *E. radiata* gives the best oil yield, 3.5 per cent of the weight of the leaves. *E. diversicolor* yields 1.2 per cent and *e. regnans* 0.9 per cent. Eucalyptus oil has considerable commercial value, but from the viewpoint of human nutrition, the oil yields per hectare are too low to be of real importance.

The black plum (*Eugenia Jambolana* or *Syzygium cumini*) also belongs to the same family. The name *Eugenia* comes from Eugene, Prince of Savoy, a patron of botany in the seventeenth century. Syzygium is from the Greek *suzogos* or 'paired'. *Jambolana* comes from the East Indies word *jambos* or 'rose apple' which found its way to Hindi as *jambu* and then *jamun*. The name *phalendra*, by which the tree is also known, means 'chief of fruit-giving plants'.

The jamun tree almost certainly has its origins in India. It is considered sacred to both Krishna and Ganesha. It is venerated by Buddhists too. The god of the clouds, Megha, is supposed to have been incarnated on the earth as jamun and that is why the colour of the fruit is that of the sky when a storm approaches. The leaves of this tree are strung into garlands and hung over the entrance doors of houses to ensure perpetuity and continuity and a stable marriage. It is planted near temples and Brahmins are fed in its shade.

Jamun is a large, dense, long-lived evergreen tree. It prefers to grow in a tropical and subtropical climate, but the tree is also found in the lower ranges of the Himalayas up to an altitude of 1,300 metres. The fruit is a small, juicy, oval plum, pink and green at first, then turning purple-black as it ripens. Each fruit contains one large seed. Fruits have a high calorific value and they are very rich in iron. Thus, eating them is a way to fight anaemia. The powdered seeds have a reputation of being useful in the treatment of diabetes.

They are reported to diminish the quantity of sugar in urine very quickly, and in some cases even permanently. The seed is also fed to cattle.

The leaves of the jamun tree are fed to tussar silkworms. The fruit is juicy and sweet and eaten by people, birds and even horses. It is also turned into juice, vinegar and alcohol. When 100 trees are planted on each hectare, the mature seed-grown trees annually produce an average of 80 to 100 kilograms of fruit per tree. The wood has timber value, and is used for railway sleepers, because it is strong and tolerant to insect and fungal attacks. It is also used to make agricultural implements.

## The Fig Family (Moraceae)

The fig family includes several important genera, three of which will be mentioned here. One is the very large genus of figs (*Ficus* spp) that contains about 900 species. The second is the breadfruit genus (*Artocarpus* spp), which includes breadfruit, jackfruit and a number of their relatives. The third one is the mulberry genus (*Morus* spp).

In the rainforests, figs are usually the most important fruit trees. In the Asian rainforests, wild figs form about half of the food eaten by large primates. It has been estimated that 40 per cent of the food of all fruit-eating animals in the Amazonas comes from wild figs. The so-called strangler figs are epiphytes, plants growing on top of other plants. Or, to be more precise, they begin their lives as epiphytes. Their seeds are spread by birds and by other fruit-eating animals. They germinate on the forks or cracks of other trees and send down aerial roots which develop to ordinary root systems when they have reached the ground. The aerial roots of a strangler fig can finally envelope the trunk of the host tree in its entirety, smothering it to death. For this reason, the strangler figs that have grown around a host tree often have rather impressive trunk diameters.

The largest African strangler figs growing outside the rainforests (like *Ficus kirkii* and *F. sansibarica*) can grow to more than 40 metres in height, and attain almost baobab-size dimensions in thickness. The stranglers growing in the rainforests of Africa, Asia and South America can be still larger.



Numerous figs, besides the domesticated Mediterranean fig (*F. carica*) produce edible fruit. The fruit are nutritious and the trees bear huge quantities of them. In spite of this, almost nothing has been done to domesticate even the most promising southern fig species and to improve them as fruit-producing trees. One of the reasons is that wild figs are not usually considered desirable food, in spite of their good nutritional value: they are often infested by insects, which greatly reduces their attractiveness as human food.

Still, one cannot travel in Africa without paying attention to wild fig trees which still seem to be growing almost everywhere, and which often bear—during the fruiting seasons—very, very impressive fruit crops. So it should at least be asked why some of the wild figs do not receive more attention as fruit and carbon storage trees?

Breadfruit trees are among the most productive food plants known to man. The breadfruit (*Artocarpus altilis*) can become 25 metres tall, but usually remains much shorter. When the breadfruit trees are grown 10–15 metres apart (50–100 trees per hectare), mature trees can be expected to produce an annual crop of 700–3500 kilograms of fruit per tree. The fruit is produced throughout the year, and there can be up to three harvests. The fruits are smaller than jackfruit, but they can still weigh up to two kilograms. The calorific value of the fruit (474 kj/100g) is one and a half times better than that of the potato. The fruit also contains 1.5 per cent protein.

The seeded varieties of breadfruit are called breadnuts. In most seeded varieties, there is relatively little edible pulp, because it has been replaced by a mass of brownish seeds an inch or more in length and up to one inch in diameter. There are usually 16–24 nuts in each seeded fruit. The seeds can be roasted and eaten and their taste resembles that of chestnuts. The nuts contain 11 per cent protein and their calorific value is high (1642 kJ/100 g). Because of the high nutritive value of the nuts, the seeded varieties are more important from the viewpoint of food security, although the varieties that do not contain any seed are usually more popular among the people.

Jackfruit (*A. heterophyllus*) is a close relative of the breadfruit. The species most probably has its origin in South Asia, and the

slightly idiotic English brutalization 'jack' has been derived from the fruit's Sanskrit name *tchackka*. Jackfruit produces a very impressive fruit that can become up to one metre long. According to W. Lötschert and G. Beese, a single tree can bear 220–260 fruit, each weighing 20–30 kilograms. This means that jackfruit trees can produce enormous amounts of food.

However, the yield varies a lot according to the productivity of the trees and according to the climatic conditions: a single tree can produce only a few or several hundreds of fruits, the weight of which varies from one to 50 kilograms. A crop between 500 and 700 kilograms per tree is, in many cases, considered quite good.

The fruits are slightly less nutritious than those of the breadfruit, having a calorific value of 394 kJ/100g. However, they contain a little bit more protein than breadfruits.

The jackfruit also contains edible, protein-rich seeds. They can be up to five centimetres long, and they are very tasty when roasted. One of the most promising trees that has been identified by Indian scientists produces about 200 fruit per year, each of which contains almost one kilogram of seeds.

Breadfruit are the staple food on many Pacific islands, and the breadfruit and jackfruit trees are grown on a small scale in many other tropical countries. However, compared to their potential, they have not really received the attention they deserve. In most tropical countries, they still remain a minor crop. Introducing these trees to the countries and areas where they are not yet known, but where they could be grown with good results, is highly recommended.

According to the literature, breadfruit and jackfruit are not, even in the tropics, suitable for growing in altitudes higher than 1,500 metres. It seems, however, that this limit can be extended quite easily with some experimentation and patience. For example, the tree nursery groups of the Green Belt Movement of Kenya have very successfully promoted the growing of these trees above the altitude of 2,000 metres in the Kenyan highlands.

The farmers who started to domesticate the breadfruit and the jackfruit in South Asia and in the Pacific, did some selection initially, but there has not really been any focussed breeding and improvement efforts involving these valuable fruit trees.



Besides fruit, the artocarpus species also have a number of other uses. Their leaves constitute an excellent fodder. Jackfruit also produces valuable timber. It turns dark with age, starting to resemble mahogany, and it can be used in the making of high-class furniture. Both jackfruit and breadfruit are usually grown mixed with other trees, bushes and annual crops. Besides this, yam plants are often trailed on them.

The artocarpus genus contains 50 different species, 25 of which grow on the island of Borneo. Only breadfruit and jackfruit are currently cultivated on a larger scale. The other species of the genus definitely deserve more research attention.

### *The Banyan and the Pipal*

Two members of the fig genus, the banyan and the pipal, have unique religious significance in South Asia. The banyan tree (*Ficus benghalensis*) has been described as the most astounding piece of vegetation on the face of this earth. It is an evergreen tree, which grows to about 30 feet in height. It sends down roots from its branches and these enter the ground and become trunks. At first the roots are slender, but as soon as they anchor themselves, they become thick pillars that bear the weight of the heaviest branches.

The leaves are broadly oval, deep green above and pale green underneath. They are smooth and shiny when young, and stiff and leathery when old. If broken, they ooze a milky white fluid. The flowers and fruit are inconspicuous. The fruit is a green hard fig that emerges from the angle between the leafstalk and the branch and turns red and soft as it matures. Almost all birds eat the fruits.

How wide does a banyan grow? The tree in Chicholi, Hoshangabad, is an acre and a half wide. In Chuchanakuppe, near Bangalore (Karnataka) the tree, said to be five centuries old, is almost three acres wide. From a seed planted in 1792, the tree at the Botanical Gardens of Sibpur, Kolkata, has grown to a size where its trunk is larger than 15 metres in girth and it has over 1,000 aerial branches, its canopy covering four acres. The tree in Satara was last measured in 1882 when its circumference was 483 metres.

The name 'banyan' is said to have been given by the British to a tree under which *Banias* or Hindu merchants assembled for busi-

ness and worship. *Ficus* means 'fig' and *Benghalensis* is of, or pertaining to, Bengal. The Sanskrit name *vata* means 'to surround or encompass'.

The banyan, the Ganga and the Himalayas, these three symbolize the image of India. To most Indians, the tree is sacred and only in the most dire circumstances, like a famine, will its leaves be plucked for cattle fodder.

The tree symbolizes all three gods of the Hindu Triad. Vishnu is the bark, Brahma the roots and Shiva the branches. Another name for Kubera, the treasure-keeper of the gods, is *Vatashraya*, 'one who lives in the banyan tree'. According to tradition, it is visited by the goddess Lakshmi on Sundays. The Puranas tell the story of Savitri, who lost her husband a year after her marriage. He died under a banyan tree and, by worshipping this tree, Savitri succeeded in bringing him to life again. This legend has given rise to a special *puja* that is done on Vat Savitri day when women fast and go round the banyan tree.

Banyan trees were regarded as symbols of fertility, venerated by those who wanted children. The Mahabharata tells of a mother and daughter who embraced two banyan trees and became the mothers of Sage Vishvamitra and Sage Jamadagni.

In the Hattipala Jakata of the Buddhists is the story of the woman with seven sons. She said that she prayed to the deity of the Banyan tree, who blessed her with sons. A pilgrimage to one of the main banyan trees is considered the equivalent of 12 years of sacrifice, and it is believed that one who anoints himself with the ashes of any part of this tree, becomes free of sin.

In Hindu mythology, Vishnu was born under the shade of the banyan tree. One of the earliest forms of Indian sculpture is the Kalpavriksha or 'wish-granting tree' of Besnagar, now in the Indian Museum, Calcutta. It has been identified by Ananda Coomaraswamy as a banyan tree. The Aryans portrayed Indra as sitting with his queen, shaded by a banyan from whose branches people gathered jewels, clothes, food and drink. Also called the *Agastyavata*, it symbolizes immortality. When the whole world was flooded during the Great Deluge, a leaf of the banyan tree cradled Balmukunda safely through the waters.



Another very important member of the genus is the peepal or the pipal tree (*F. religiosa*). The Sanskrit word for the tree, *Ashvattha*, means 'under which horses stand'. *Bodhadruma* means 'the tree of perfect wisdom'. The name *pipal* has an interesting origin. The pipal tree has a resemblance to the poplar and aspen trees in that its leaves also shake. Aryan immigrants, seeing the tree for the first time, gave it the name of the *poplar* or *pappel*, a tree they were familiar with in the northern latitudes. Even now in Italy, the transplanted pipal is called *populo delle Indie* or 'the Indian poplar'. In the earlier descriptions of Indian flora, it was called 'the poplar-leaved fig tree'.

The pipal is the oldest depicted tree in India. In Vedic times, it was used to make fire by friction. Considered a sacred tree, the pipal is seldom cut. It is associated with the Triad, the roots being Brahma, the stem Vishnu and each leaf being the seat of a minor god. The Ashvattha Stotra says: 'I bow to the sacred fig tree, to Brahma in the root, to Vishnu in the trunk and to Shiva in the foliage.' In another myth, Vishnu was born under a pipal and is therefore considered the tree itself. Yet another legend has it that the gods eavesdropped when Shiva and Parvati were talking and playing together. An enraged Parvati cursed all of them to be reborn as trees. Brahma became the palasa, Rudra the *F. indica* and Vishnu the pipal.

The pipal is considered a Brahmin tree and Brahmins offer prayers under it. In Gujarat, it is considered a Brahmin itself and invested with the sacred triple cord. It is considered that one who cuts it has murdered a Brahmin and his family will soon become extinct. It is served with food offerings when a male member of the family dies.

Some communities believe that the spirits of the dead do not get water in the next world. The pipal is considered as a pathway. So water is poured on its roots on three days of the dark half of Kartik (mid-October to mid-November) and Shravana (mid-July to mid-August) and on the fourteenth day of the bright half of Chaitra (March-end).

The pipal is often married to the nim (neem) or to the banana. If the trees grow together, they are considered husband and wife.

On Amavasya, the last day of the dark half of the month, particularly if it is a Monday, villagers worship these trees and perform a symbolic marriage between them. After the threads are tied, they circle the trees 108 times to remove all their sins. Manasa, the goddess of serpents worshipped in Bengal, is said to live in the pipal tree. Krishna was shot by a hunter's arrow while he sat under it.

The pipal is sacred to the Buddhists, as Prince Siddharta received enlightenment under it in Bodh Gaya and became the Buddha. Hence it is also called the *Bodhi Vriksha* or 'the Tree of Enlightenment'. The Chinese traveller, Huen Tsang, gives an account of this tree. In the olden days, he says, when Buddha was alive, this tree was several hundred feet high. Often injured by cutting or breaking for relics, it is now only 50 feet high. Buddha reached perfect wisdom under it, so it is called the *Samyak Sambodhi* or 'Tree of Knowledge'. The bark is yellowish white, the leaves dark green. The leaves remain shining and glossy the whole year. But on Nirvana Day, they wither and hang their heads, then in a little while revive as before. On this day of Nirvana, many princes assemble and bathe the roots of the tree with scented perfume and milk and offer gifts.

The pipal tree in Sri Lanka is believed to be 2,147 years old. It was believed that the ruling dynasty of Buddhists would last as long as the tree survived, and for this reason it was well looked after. In Purabi, the dialect of eastern Uttar Pradesh, there is a saying used when expelling evil spirits or when talking of someone's evil temper. It goes:

> *Je Jagdipen nagar ujaaral, raakas chhoral pipar*
> *Se Jagdipa aawat baru, haathe le le musar*
>
> or
>
> Jagdipa, who made the town desolate and from
> whom even the demon fled the Pipal, is now
> coming with a pestle in her hand.

Jagdipa was, in folklore, an exceedingly quarrelsome woman. She fought with everyone in the village, all the time. She abused and hit them and made life so unpleasant, that the villagers started leaving the village, settling down elsewhere.



## The King and the Gardener

Once on a hot summer day, the king of the land, on a visit to the distant parts of his realm, came to a garden. The king was very thirsty. He got off his horse and entered the garden gate. He saw a gardener tending pomegranate trees. Each tree was laden with fruit.

'May I have some pomegranate juice?' asked the king.

The gardener plucked a ripe pomegranate fruit and took it to his hut in the corner. In a few minutes, a beautiful maiden brought a cupful of fresh rich juice for the king. The king, his eyes dazzled by the girl's fair face, drank the juice greedily. His thirst quenched, he looked around the garden and saw fruit trees growing wild everywhere.

'How much profit do you make from selling this fruit?' he asked the gardener.

'Three hundred dinars,' replied the unsuspecting gardener.

'And what do you pay the king's tax collector?' asked the king.

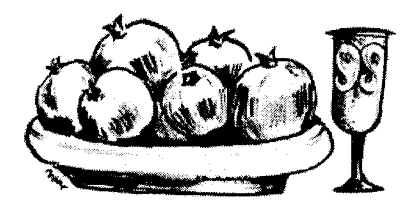
'The king only takes one-tenth of the cultivated grain. He does not take any money from the fruit,' answered the gardener.

The king saw the profusion of pomegranate trees. 'I have so many trees all over my kingdom,' he thought. 'I must start taxing orchards as well.'

Pleased with his plan, the king decided to return immediately to his capital. He swung onto his horse, but before leaving he asked for some more pomegranate juice.

The old gardener had recognized the king but had pretended ignorance. He could almost see the thoughts passing through the king's mind as his eyes roved greedily over the pomegranate trees. Both he and his daughter went back to the hut and came out with a cup. But this time the cup had only a few drops of juice in it. The king was puzzled.

'Where is the juice?' asked the king.



'My lord, when you asked for pomegranate juice the first time, your heart was large and the pomegranate gave its juice freely. But now I have squeezed five pomegranates and this is all I could get.'

The king turned to the gardener.

'Can you explain this to me, gardener?' he asked.

'It is simple, my lord. Our king has a large heart. He lets the fruit grow wild and everyone partakes of it. The fruit knows it has his blessing, so it gives of its juice generously. Today, the fruit has felt that the king wishes to impose a tax on it. So it feels that the blessing has passed from it. And its juice has dried up.'

The king felt ashamed of his greedy thoughts. He banished the idea of imposing a tax from his mind and his brow cleared. The gardener watched his mood change.

The king asked for more juice. This time his cup brimmed over with red juice. He thanked the gardener and his beautiful daughter and rode away.

One day, there was no one left to quarrel with. Jagdipa was undaunted. She picked up her broom and attacked the pipal tree, shouting abuse at it all the while. The demon in the tree, no faintheart himself, stood it for a few days. But, finally, even his nerve gave way, and he rushed away from the tree and sought refuge elsewhere.

The pipal is a very large tree. The bark is light grey and smooth and peels in patches. The young branches are smooth and shiny. The long leaves grow on long stalks and are a shiny dark red when young. They are smooth, leathery, heart-shaped tapering at the apex into a long tail. The leaves hang down and the slightest breeze makes them tremble and rustle.

The flowers are inconspicuous and colourless and are hidden by the figs when they emerge in pairs between the leaf-stalk and the branch. At first, the fruit is green and smooth and then turns purple when ripe. The figs are eaten by birds and bats. Each part of the tree is used in ayurvedic medicine. The leaves are fed to camels and elephants. The bark contains tannin and is sometimes used for tanning leather and to make a red dye.

### The Strychnos Family (Loganiaceae)

The name of the strychnos genus comes from strychnine, a powerful poison derived from one Indian (*Strychnos nux-vomica*) and one South American (*S. toxifera*) species of the genus. However, very few Strychnos species actually have toxic properties.

The Loganiaceae family is mentioned here because of two members of the Strychnos genus: the wild orange (*S. spinosa*) and the monkey orange (*S. cocculoides*). Wild orange and monkey orange are not large trees, but they can produce large quantities of nutritious food in arid conditions.

In Botswana, a superior phenotype of monkey orange, producing 700 to 800 large fruit (400–600 kilograms) in a season, has been found from the wild. One fruit has a street value of about US 40 cents. The fruit has a hard shell, a kind of a natural tin, which gives it a shelf life of up to three months. One tree like this can thus yield a crop valued at about US$ 140 in one season, without any input. This is more than most subsistence farmers in Botswana earn during an average year, after a lot of sweat. In other words, the planting



of a single desert fruit tree can more than double the income of a poor rural household.

The calorific value of wild oranges is about 420 kJ/100g, 40 per cent higher than in potatoes.

### The Avocado Family (Lauraceae)

Of the 2,500 species belonging to the Lauraceae family, the avocado is undoubtedly the most important. Excluding the fruits of the palm and nut trees, avocado probably is the most nutritious fruit that is currently being cultivated on a large scale. Its calorific value is 685 kJ/100g, and it contains a rich mixture of valuable fats and some protein. Because the fruit has a 25–30 per cent oil content, it is sometimes called the poor man's butter—but it could be argued whether butter made from cow's milk has more finesse than that made from avocados.

Avocado oil mostly consists of oleic acid, which means that it is a very healthy fat, and can contribute to the prevention of heart disease.

The largest known avocado trees are about 20 metres tall.

The highest reported annual hectare yields have been around 20 tonnes, but average yields are much lower, probably somewhere between five and 10 tonnes. Because of the high nutritive value of the fruit, even the lower yields are significant in terms of human nutrition. Yields could probably be improved in a major way by selective breeding. Individual avocado trees growing on African highlands have been reported to yield up to 800 kilograms of fruits in one fruiting season.

Avocado is, like the pawpaw, a gift to the world from the ancient peoples of Central America. Aztecs and Mayas cultivated it on a large scale. According to some estimates, the fruit was probably domesticated as far back as 8,000 years ago.

The camphor tree (*Cinnamomum camphora*), providing the valuable camphor oil, belongs to the same family. The largest individuals can attain a substantial size. One of the most famous is the camphor tree of the temple of Kagoshima in Kano, Japan. It has a diameter of seven metres at shoulder height.

A third tree species that should be mentioned here is the East African camphor wood or muthaiti (*Ocotea usambarensis*). It is one of the largest trees growing in eastern Africa. It can reach a height of 50 metres. It has a massive trunk, the diameter of which often exceeds three metres. Because the tree has now become very rare everywhere, it is difficult to find larger specimens, but there have been unverified reports about felled muthaiti trees with a diameter of seven or eight metres.

One of the authors (Risto Isomäki) once measured a muringa (*Cordia africana*) tree that had just been felled in the Kirinyaga district of Kenya. The tree had a diameter of 4.5 metres at shoulder height, even though the books say that muringa can only reach a thickness of one metre or so. There are hardly any muthaitis left in the area. However, all the older people say that it used to be, by far, the thickest tree that grew in the forest. According to the elders, muringa was the second largest tree in the forest, but the muthaiti became still larger and thicker. Because of the unanimity of these testimonies, the stories about eight-metre-thick muthaitis do carry a ring of truth.

### The Baobab Family (Bombacaceae)

The baobab (*Adansonia digitata*) might well become, from the viewpoint of absorbing atmospheric carbon dioxide, the most important tree species in the world. Sequoia and sequoiadendron stands can probably form larger per hectare storage of organic carbon. However, it is not likely that they will be grown on very large areas, because they do not produce food for human consumption.

Baobab grows well in areas that cover one-third of the African continent, or a combined land area of almost 1,000 million hectares. The natural range of baobab stretches from Sahel and Sudan all the way down to Transvaal, in the Republic of South Africa. Baobabs can grow well in very dry conditions, but they also grow in coastal areas with a much higher rainfall. It is likely that many, if not most, people living in these areas would be willing to plant and grow more baobab trees, because of their numerous uses and benefits.

There are other trees that—like the baobab—can survive in dry conditions. However, no other species survives the drought in as spectacular a fashion: the baobabs grow immense trunks and vast root systems into which they store large quantities of water.



In the words of the botanist Veronica Roodt:

> Undoubtedly this magnificent colossus is the most frequently-discussed botanical phenomenon in Africa and its pre-historic appearance provides for one of the most dramatic landscapes Africa has to offer.

The average stem diameter of a large baobab is about five metres, but a diameter of nine or 10 metres is not uncommon.

The largest measured baobab (which was felled after being measured) was 18 metres in diameter, which could be an all-time world record. The largest still existing specimen in the Republic of South Africa has a circumference of 47 metres.

Baobab trees do not grow very tall, but because of their immense thickness, even a relatively low baobab tree can contain a vast volume of wood. The odd shape of the tree also contributes to the volume of wood: the trunk diameter can be almost the same at the ground level and where the actual trunk ends. Because the thickness of the tree is determined by two dimensions, and the height of it by only one, it is easy to underestimate the amount of wood in a very thick but relatively low tree. If the trunk of the largest measured baobab really was 18 metres in diameter and about 15 metres in height, the mere trunk of this giant would contain about 4,000 cubic metres of wood.

Not been much research has been done on the root systems of the baobab trees. However, in the drier areas, up to two-thirds of the biomass of many trees is sometimes below the ground. It is likely that this rule does not apply to baobab trees, but the amount of carbon stored in their vast roots and thick branches could still be substantial.

Baobab wood is soft, spongy and light, with a dry weight of only 0.32. From the viewpoint of carbon sequestration, this means that each cubic metre contains less carbon than the wood of most other tree species. However, the sponginess of the wood is also a benefit. Because of this quality, it is actually quite safe to store carbon dioxide in baobab trees: they contain so much moisture that they cannot burn in any kind of forest fire. Because of the high

moisture content, freshly cut baobab wood could only be burnt in a middle-sized or large thermal power plant. This definitely isn't a good fuelwood tree!

The largest baobabs grow at low altitudes, usually in coastal areas. In the national parks of Africa, the large baobabs often dominate the landscape, but there can be hundreds of metres or even kilometres between two baobab trees. The main reason for this is probably the elephants, who find the whole baobab tree very palatable until it is three years old. The seedlings are also eaten by cattle. Large baobabs used to be much more common before ruthless exploitation reduced their numbers. Baobab wood is worthless as timber, but it is very suitable for manufacturing paper. After this was discovered in Madagascar in 1916, larger baobab trees were exterminated from large parts of southern and eastern Africa, before botanical institutions came to their rescue. Countless baobabs have also been destroyed because of the most useful fibre of their bark. The stripped, pounded and soaked bark can provide pieces of a fibrous material up to 1.5 metres long. They can be used in the making of fishing nets, sacks and even clothes.

During our time, baobabs have totally disappeared from large areas where they used to grow. On the other hand, there are often dense groups or even forests of old baobabs growing near rural villages. It is possible that most of them were planted by humans, or grew from seed sown by them, centuries or millennia ago. Some of these baobab stands might actually be the oldest still living trees that have ever been planted by humans. By reviving and expanding the tradition of establishing small baobab forests near each village, food security in rural Africa could be improved in a most significant way. In many areas this is already happening: people are planting baobabs near their homes or leaving baobab seedlings untouched while they cut other trees. When scientists working for ICRAF (International Center for Research on Agroforestry) asked the people in five West African countries which they considered to be the most useful native trees in their area, baobab collected three first, one second and one third place. Baobab is esteemed so highly mainly because it produces large amounts of nutritious food even during the drought years.



Baobab fruits are large: they can be 30 centimetres in diameter. They have, in spite of their size, an astonishing nutritive value and contain 1287 kJ of energy for 100 g of fresh fruit. In other words, the calorific value of the baobab fruit is almost as good as that of rice and about four times higher than that of the potato. The protein content is around three per cent. Each fruit contains about 100 large seeds, the size of which is about one cubic centimetre. The seeds can be roasted and eaten, and they contain 30 per cent protein, 30 per cent fat and 25 per cent carbohydrates.

Because of their wooden shell the fruits keep well, and the shells have numerous different uses. Also, the leaves and the roots of young trees are edible. The leaves are, nutritionally speaking, equivalent to spinach, and they are commonly used in cooking in many African countries. Baobab fruits are exceptionally rich in vitamin C, and the leaves contain large quantities of vitamin A. As mentioned before, vitamin A deficiency increases the mortality due to diarrhoeal and respiratory diseases among children, besides which it can also cause blindness. The more frequent planting of baobab trees could solve this problem in the drier parts of Africa. However, oil made of baobab seeds contains a much larger percentage of saturated (unhealthy) fats than that of olive, marula, mongongo or avocado oil.

In continental Africa, there is only one baobab species, but in the island of Madagascar there are six different species, one of which is the same as that which occurs on the continent. The characteristics and biology of the five other species are much less known than that of *A. digitata*, but they would definitely deserve more research attention.

Many people in Africa still think that there are no young baobabs. According to an ancient legend, the old, fully developed baobabs fall from the heaven when they are ready. It is easy to understand why such beliefs have developed. In large areas, there are no longer any young baobabs left: they have disappeared along with the other woody vegetation. But the landscape will still be dominated by a single old baobab or groups of them, which may look exactly the same as when the grandfather was a young boy.

It is not known how old baobabs can become, but they definitely are among the oldest trees in the world. It is even possible that they occupy the first place, if trees like aspen—whose root systems can survive for immensely long periods of time—are excluded.

Baobabs do not have growth rings, so the only reliable way of dating them is the radio carbon method. Zimbabwean researchers using this method estimated that a baobab tree which was five metres in diameter was about 1,000 years of age. Larger specimens with a diameter of nine meters were estimated to be more than 4,000 years old.

It seems that baobabs grow fast during their first 270 years, reaching a diameter of about two metres during this time. Later, the growth becomes much slower. One baobab that was described and measured by David Livingstone, had only increased its circumference by 0.6 metres when it was measured again, 110 years later.

We know that the largest baobabs that used to be around in Tanzania and in some other countries were up to 18 metres in diameter. If the growth of the ancient trees becomes progressively slower the older they get, the largest baobabs may be very old, indeed.

Even the fiercest of storms can never fell a large baobab.

While the centuries and millennia pass by, the old baobabs begin to rot, little by little, until they become hollow shells. Because of their unbelievable strength and life force, they can still remain productive, bearing crops of fruit and offering homes for bee communities, birds and other animals. Little by little, the hollow skeleton of the ancient baobab dies and crumbles to dust. Finally, only a small hill or a pile of soil, gradually levelled by the winds blowing on the savannah, reminds one of the life of a great baobab.

A distant relative of the baobab tree, the durian (*Durio zebethinus*) should also be mentioned. The durian is one of the most important indigenous fruit trees in southeast Asia, and its fruits are sold in every market in Indonesia, Malaysia and Thailand. The tree can grow more than 40 metres tall. The fruits are as big as a human head, and can weigh up to three kilograms. There are usually two harvests in a year. The fruits contain chestnut-sized, edible seeds.



## The Araucaria Family (Araucariaceae)

The araucarias (*Araucaria* spp) are the most important genus of conifers in the Southern Hemisphere. Some species, especially *A. columnaris*, *A. cunninghamiana* and *A. heterophylla* can reach a height of 70 metres. *A. bidwilii* or the bunya bunya pine can also grow to more than 50 metres. The trunks of the largest trees may be three metres in diameter.

The cones of many species contain large seeds that are edible.

The seeds of *A. araucana* are still the staple food of more than a million indigenous people living in the southern Andes in South America. The name of the whole genus, in fact, has been derived from one of these tribes: the araucarian people.

Bunya bunya pine has had similar significance for the aborigines in Queensland, Australia. The female cones of the bunya bunya are huge, on average 30 centimetres long and 23 centimetres wide, and they can weigh more than five kilograms. Each cone contains hundreds of nutritious seeds which are, on average, six to seven centimeters long and three centimetres wide. Also, the seeds of *A. columnaris* and *A. heterophylla* are relatively large, with a diameter of three centimetres or so, but the seeds of *A. cunninghamiana* are so small that it is not of much use to collect them for food.

Because araucarias can achieve substantial heights and grow massive trunks, and because they also produce a substantial amount of edible seeds, they may well have some importance as carbon storage trees.

Besides the araucaria genus, another magnificent tree belonging to the same family must be mentioned here. The species in question is kauri (*Agathis australis*), which is one of the most spectacular tree species in the Southern Hemisphere. According to the geographer Allen Keast, mature kauris have an average diameter of three metres and an average height of 30 metres. However, the really old kauris—which can be more than 2,000 years old—can grow still larger and attain a height of 60 metres and a diameter of six metres. The largest measured specimen produced 889 cubic metres of marketable timber when it was felled.

The most famous tree in Aotearoa (New Zealand) nowadays is a 52-metre-high kauri, which has a diameter of five metres at shoulder height. Maoris call the tree Tane Mahuta, the King of the Trees. When the European settlers arrived in New Zealand, kauri forests still covered about 800,000 hectares. Now less than 10,000 hectares are left.

## The Rose Family (Rosaceae)

The rose family includes 3,000 species, most of which are trees or shrubs. Most of the fruit trees growing in temperate or northern regions belong to this family, which includes, for example, apples (*Malus* spp), pears (*Pyrus* spp), cherries, apricots, peaches, nectarines, almonds and plums (*Prunus* spp), loquats (*Eriobotrya* spp), rowans (*Sorbus* spp) and quinces (*Cydonia* spp). Roses (*Rosa* spp) are, of course, members of the family, as well as many important wild berry-producing shrubs, like the genus *Vaccinium*.

In this context, we will concentrate on two genera of this very important family: apples and rowans (or mountain ashes).

Most peoples in the world have eaten famine foods produced by wild trees during hard times, and they therefore consider these important wild, food-producing trees as holy and sacred. For the Finns and other Finno-Ugric peoples, the most sacred tree used to be the rowan (*Sorbus aucuparia*), and it is still a very popular homestead tree in Finland.

The rowan is not a very large tree. In Finland, the largest specimens have a diameter of 70 centimetres, and the tree seldom reaches a height of 20 metres. But the rowan is an important and interesting tree, because it can produce large crops of edible berries in conditions which are too cold for all other food-producing trees, except cembra pine and some members of the seabuckthorn genus (*Hippophae* spp). The rowan also produces fine and valuable wood that is harder and of a finer quality than that of oaks and beeches. For this reason, it has sometimes been called the mahogany of the North.

It is difficult to find estimates about the hectare yields of rowan cultivation. However, the production of berries is cyclical: between



the bumper crops, there are usually one or two years during which the production of berries is much less. In 1998, which was a good year, one 12-metre-high rowan tree, monitored by the Finnish Coalition for Environment and Development and growing in the middle of larger trees, produced 180 kilograms of berries. The diameter of the tree's canopy was, on average, seven metres, so in a monoculture, there would be room for 200 trees of a similar size on each hectare.

The berries are quick to collect, and relatively nutritious. Their calorific value is slightly less than that of potatoes (one-fourth of the calorific value of rice) and they contain large quantities of vitamins A and C in a very useful form. The main problem limiting the use of the berry crop is the high acid content. Most of the berries are too sour for human consumption.

It is possible to neutralise the acid by putting the berries in salty water (with three per cent salt) for two days and by washing them with warm water after that. Another solution is to breed cultivars that produce sweet berries. That would not be too difficult, because some wild trees do produce sweet berries. The easiest way of finding such trees is to follow the birds, which usually eat the sweetest berries first. The rowan produces large berry crops even in the most northern parts of Finland, which occasionally experience temperatures below –50 centigrade. Many rowans, growing at higher altitudes on the fells and mountains of Lapland, must have survived even lower temperatures.

Large rowans producing good berry crops often grow on bare rock: their roots have an ability to penetrate deep into the middle of the rock through small fractures to extract the necessary moisture and nutrients.

Rowans might have some use as food-producing trees both in the northern areas and in the high mountains of the Himalayas and the Andes. The Hindukush-Himalayan region has dozens of indigenous sorbus species, which could be domesticated to become important fruit trees at heights where other food-producing trees cannot be grown. When it comes to the Andes, it might be a good idea to introduce some of the sorbus species to the higher areas on an experimental basis.

The domesticated apple (*Malus domestica*) is the unchallenged queen of the fruit trees grown in the more northern latitudes.

The best annual hectare yields recorded in India have exceeded 60 tonnes. The nutritive value of apples is comparable to potatoes. Apple trees do not require good soil, and can easily be grown on steep hillslopes or rocky land that cannot be used for the cultivation of annual crops.

Some wild apples were probably planted by people near their homesteads even during the Stone Age. Our present, domesticated apple is a complex hybrid that has received genes from various wild apples, and its origins have been impossible to trace. The northern frontier of apple cultivation has progressively moved farther to the north during the millennia. Twelve hundred years ago, in the 800s, for example, France was considered too cold for apple cultivation. Since then, the northern frontier of apple orchards has been pushed northwards by about 1,500 kilometres.

The perennial, berry-producing shrubs that belong to the vaccinium and empretum genera deserve mention, even though they are not trees. In the Arctic tundra, the empretum shrubs or crowberries often dominate the vegetation in vast areas. These wild shrubs produce, in Finland alone, between 150,000 and 250,000 tonnes of edible berries in a year, most of these in the fell and tundra areas of Finnish Lapland. These areas, however, cover less than one per cent of the total area of the Arctic tundra. The tundra as a whole must produce a vast annual crop of crowberries!

The various vaccinium species form an important part of the undergrowth in the whole northern evergreen forest zone, covering more than 20 million square kilometres or two billion hectares of land. The most important species are cranberry (*V. vitis-idaea*) and blueberry (*V. myrtillus*). In most cases, cranberries and blueberries form small patches in the middle of other undergrowth in the forest. In this kind of situation, the berry yield is typically between 10 and 100 kilograms per hectare. However, if a forest has an optimal density for either cranberries or blueberries, they can cover much of the ground in almost pure mats of berry-producing shrubs. In such natural monocultures (or near monocultures) the annual crop of wild blueberries can reach 2,500 kilograms and the crop of



cranberries 2,100 kilograms per hectare. Both berries are relatively nutritious and rich in flavonoids.

It would, in theory, be possible to multiply the natural production of blueberries and cranberries in the northern forests by changing the forest management practices. In the present system, a patch of forest only produces larger amounts of berries for a rather short period during each tree-growing cycle. If the density of the forests could be kept close to optimum for blueberries or cranberries, they would perhaps produce almost pure growths, and very large berry yields. At present, such practices do not make much sense, because there is no one to collect the berries with the present prices paid for them.

Small cranberry (*V. oxycoccus*) and the larger cousin of the blueberry (*V. uliginosum*) often dominate the vegetation in the vast peatland areas in Northern Europe and Siberia. They produce edible berries, the yield of which can reach 500–600 kilograms per hectare.

## The Seabuckthorn Family (Elaeagnaceae)

Seabuckthorns (*Hippophae* spp) are hardy bushes or trees that can be grown at high altitudes in the mountains or in the far north. Some species tolerate temperatures below –60 degrees Celsius. They can survive severe drought and grow well in areas where the average annual rainfall is below 200 millimetres. Seabuckthorns have adapted to diverse conditions and survive on poor soils. Their ability to grow on marginal lands is largely due to their deep root systems and their capability to fix atmospheric nitrogen with the frankia microbes living in their root nodules.

The genus probably has its origins in the Himalayas, but it has spread from there to the Alps and to the coastal areas of the Baltic Sea. There are at least five different species and a number of subspecies.

Seabuckthorn has recently become a real superstar in the erosion control and reforestation programmes implemented in the cold, mountainous regions of China. Seabuckthorn stands planted by such programmes already cover about 1.4 million hectares, most of which are in China. Their acreage is now growing by 100,000 hectares in a year.

The popularity of seabuckthorn is based on a number of factors. Because it creates dense stands, it is very effective in controlling erosion. It is also an effective nitrogen-fixing tree: according to Chinese studies, seabuckthorn stands can annually fix up to 180 kilograms of nitrogen in one hectare of land. Chinese farmers who have alternated between seabuckthorn and potatoes have been able to double their potato yields. In the severe conditions of the high Himalayas, seabuckthorn can produce larger quantities of nutritious cattle fodder than any other known plant. In China and India, a hectare of seabuckthorn can also provide enough firewood for 15 people.

Seabuckthorns produce edible berries. The natural growths typically produce only a few hundred kilograms of berries per hectare, but Russians and Chinese have bred varieties that yield 15–20 tonnes per hectare, in very harsh climatic conditions. In the slightly warmer Alpine conditions, the best cultivars can produce still larger annual crops. In seabuckthorn cultivation, an average of 1,250 trees are grown on one hectare, and the best cultivars can produce 35 kilograms of berries per tree in good years.

One hundred grams of berries can contain up to 1000 mg of vitamin C. Besides this, they are also rich in vitamins B, P, E, K and A, and they contain eight per cent fat. A healthy oil can be produced from the seeds. Berries can be used in the production of juices, jams and jellies.

Seabuckthorn usually remains a bush or a small tree, but relatively large individuals are also known. In Muli County, Sichuan (China) there is a seabuckthorn tree which has a height of 16 metres and a trunk diameter of almost two metres. Its estimated age is 320 years, and it is still bearing fruit.

### The Willow Family (Salicaceae)

The willow family includes some extremely interesting tree species, including the aspens. Aspens belong to the same genus as the poplars (*Populus* spp). There are two widespread species: the Eurasian aspen (*P. tremula*) and the American aspen (*P. tremuloides*).

Aspens are among the oldest and largest living organisms on earth. One tree trunk usually means one individual, but this principle doesn't apply to the aspen. An aspen can grow a huge root system, from which dozens, hundreds or even thousands of different stems can emerge. The individual stems often become relatively large, up to 30 metres tall and a little over one metre in diameter, but they seldom live longer than 100–150 years. However, the organism doesn't die with the individual stem. Its root system can keep on growing and spreading for millennium after millennium, conquering land from other tree species here and there, and constantly growing new crops of stems.



The largest known aspen clone in southern Utah contains approximately 47,000 stems and covers an area of 42 hectares. It weighs more than 6,000 tons, which probably makes it the largest known living organism on earth. Researchers have estimated that some aspens living in the southern parts of the Rocky Mountains are probably about a million years old. This, of course, is a truly astonishing age even for a long-living tree.

Our eyes grow larger when we try to imagine the age of the ancient baobabs or giant redwoods. However, it is even more difficult to understand that the more humble aspens can reach an age that is 200 times older. This fact makes the planting of aspens an almost irresistible temptation to tree-lovers. Why not plant trees that can outlive, by 100 or perhaps even 1,000 times, all the cathedrals and pyramids and palaces built by the world's mightiest kings and emperors? Especially tempting is to experiment with aspen clones that would grow edible mycorrhizal mushrooms in their root systems. Such aspens could benefit thousands and thousands of future generations of human beings.

The natural range of aspens is very large, covering most of the Eurasian and North American continents. In fact, aspens are among the most widespread trees in the world. People, however, seldom understand their real nature.

### The Beech Family (Fagaceae)

The oaks (*Quercus* spp) have a unique importance in the mythology of many European peoples. The mythological world tree of the Finns and some other Finno-Ugrian tribes (and of many other European peoples) was a gigantic forest oak (*Quercus robur*). Before the age of

the humans, the leaves of the Great Oak cast a shadow on the earth, so that no light reached the ground. In Finnish mythology, the felling of the Great Oak by a giant that rose from the sea symbolizes the birth of mankind and the beginning of agriculture: after the oak had been felled, there was light and it was possible to start growing crops.

Oaks are among the most important and widespread broad-leaved trees in Europe, North America and continental Asia. There are more than 300 different species. Oaks are usually grown for their valuable timber, but many species also produce nuts (acorns) that are edible as they are. Other species bear acorns that can be used as human food, if their acid content is reduced by proper treatment.

One method of treating the acorns is to crush them and then cook them in mild limewater, so that the acid becomes neutralised. After this, the acorns can be used as relatively nutritious human food, and, for example, ground into flour that can be used on its own or mixed with various cereal flours. The acorns contain two to four per cent fat, some protein and about 40 per cent carbohydrates.

Another method followed by the indigenous peoples of California was to bury the acorns, usually with some ash or charcoal, and water them every now and them until they became sweet and good to eat. According to an American writer, the result was

> ...a mush which has few characteristics normally associated with food ... All that really can be said in its favour is that it is an extremely substantial food, of which, with little exposure, one can become extremely fond.

There is a great variability in the yields of acorns depending on the species, on the season and on various environmental factors. According to J. Sholto Douglas, the South and North American, Korean and Portuguese oak forests typically yield between 25 and 30 tonnes of acorns per hectare in one year.

This is not a bad yield, because nobody has ever tried to select and improve oak varieties that would produce larger quantities of acorns for food or animal feed.

One of the most productive oak species is the evergreen oak (*Quercus ilex*). Individual trees have been reported to produce almost one tonne of acorns in a single fruiting season.



Oaks are not among the tallest of trees. Some species, like the forest oak (*Q. robur*) can reach 45 metres, but most species remain smaller. However, some oak species belong to the thickest trees growing in Europe. Even in southern Finland, where the forest oak is close to the ultimate northern limits of its reach, it holds the record for the greatest girth: a little bit more than eight metres. In central and southern Europe, the largest oaks can have a diameter of eight or nine metres, and reach the age of 2,000 years.

The beeches (*Fagus* spp) produce valuable timber and small nuts that are called masts, mastnuts, beechnuts or beechmasts. They can be eaten raw or roasted and salted, and taste a little bit like young walnuts. However, the masts are so small that it would be a rather tiresome business to peel enough nuts for a proper meal.

A more important use for the beechnuts used to be the production of vegetable oil. The oil yield is high, about 20 per cent of the weight of the nuts. During the World Wars, oil made of beechnuts was considered so important in Germany that schoolchildren were given special holidays for gathering the nuts. The oil was then extracted in a community mill, which was usually owned by some of the village farmers. The oil is rich in fat and proteins and remains fresh much longer than most other vegetable oils. In the USA, people also used to make butter from beechnuts, even though this habit has since been replaced by the industrial production of margarine. There is some cyclicity in the production of beechnuts, but the amounts produced in good years are prodigious.

The most important species growing in Europe and the Middle East is probably the European beech (*F. sylvatica*), which can grow 40 metres tall. There is also an American species (*F. grandifolia*), which is a very close relative of the European beech. The beeches can produce impressive girths, although they do not become quite as thick as the largest oaks.

The forests of Patagonia, the temperate region of South America, are dominated by the so-called southern beeches (*Nothofagus* spp), which are close relatives of the European and American beeches.

Ancient sweet chestnuts (*Castanea sativa*) are among the most impressive trees in the world. Sweet chestnut never grows much higher than 30 metres, but it can attain an enormous girth. Prob-

ably the largest ever recorded chestnut tree used to grow on the slopes of Etna, the famous volcano of the Mediterranean island of Sicily. The circumference of the tree, when all the fragments were counted, was an almost unbelievable 61 metres. This single tree provided the livelihood for a sizeable local industry of nut-gatherers and sellers, who eventually killed the giant by cutting its branches to make firewood in order to roast the chestnuts. When the tree finally died, bleeding from thousands of small wounds, it was 2,500 or 3,000 years old: it had been an old tree already during the time when the famous Greek philosopher Plato lived in the nearby town of Syracuse.

Dry chestnuts contain seven per cent protein, 78 per cent carbohydrates and four per cent fat. Grafted chestnut trees can provide up to 25 tonnes per hectare under intensive cultivation.

The timber is hard and valuable. Trees typically remain productive for more than 1,000 years, and sometimes for several millennia.

There are a number of other closely related species producing edible chestnuts. They include the American chestnut (*C. dentata*), the Chinese chestnut (*C. mollissima*), the Tibetan chestnut (*C. tibetana*) and the Japanese chestnut (*C. crenata*). The American chestnut can reach a height of 60 metres.

Before the arrival of the European settlers, the vast chestnut, beech and oak forests of North America supported a huge population of migrant pigeons. According to some estimates, there may have been a few thousand million of these birds nesting in these forests. This enormous bird population was totally annihilated due to the clearing of these chestnut, beech and oak forests, after which there no longer was food for similar magnitudes of wild birds and mammals.

## The Plane Family (Platanaceae)

The planes are attractive broad-leaved trees that do not produce food for human consumption, but can sometimes grow very large trunks. A specimen of eastern plane or chinar (*Platanus orientalis*) growing in Bijbehara, Kashmir, has been recorded to have a girth of 21.5 metres.



## The Lime Family (Tiliaceae)

The limes (*Tilia* spp) have a lot of importance as ornamental trees in Europe. They are among the most common trees you will encounter in the cities of north and central Europe, along the roads and in the parks.

Limes produce small berries that are very oily and can be used to make an edible vegetable oil of good quality. However, the fruits are so small that they are, in practice, hardly ever used as food.

As carbon storage trees, limes might have some significance, because they can grow to dimensions that are almost equal to those of the largest oak trees. For example, a big-leaved lime (*Tilia platyphyllos*) that was planted at Upstedt, near Hanover in Germany in the year 850, now has a diameter of eight metres 1.5 metres above the ground level. The tallest recorded lime trees have reached a height of 46 metres.

## The Swamp Cypress Family (Taxodiaceae)

This section should perhaps be titled 'the Real Jurassic Park Project'— as a tribute to the famous movie by Steven Spielberg. In *Jurassic Park*, scientists managed to bring back to life dinosaurs that had been dead for 65 million years or more. In the movie, the revived dinosaurs were supposed to become the main attractions in a hugely profitable theme park, which would have been visited by millions of rich people paying big money as entrance fees. In reality, it will never be possible to clone dinosaurs and bring back species like *Tyrannosaurus rex* or the *brachiosaurs*. However, it would be possible to recreate some of the forests that grew on earth at the time of the dinosaurs. This is easier because some of the trees that dominated the world's forests during the reign of the great dinosaurs are still growing in America as a kind of living fossil.

The oldest redwood fossils that have been discovered are about 130 million years old. At that time, the world's vegetation was dominated by diverse redwood species, by tree-sized ferns, by an enormous variety of cycads, by the ginkgo or the maidenhair trees and by swamp cypresses.

When the first redwood trees appeared on earth, vast, high-browsing dinosaurs were the most serious problem the trees were facing. Some of these giant animals were 30 metres long and weighed up to 90 or 100 tonnes. The cycads and ferns had, already in the Devonian and Permian periods, learned how to grow wooden stems. Through them the trees could raise their foliage to higher altitudes, where the browsing herbivores were no longer able to reach them. Also, the trees defended themselves by developing conifer-type leaves or needles that were not very palatable and were hard to digest.

The dinosaurs responded to these tricks by becoming larger. The huge size made it possible for the dinosaurs to digest large amounts of low-quality browse simultaneously. The largest dinosaurs have, for this reason, sometimes been described as giant, air-cooled composters walking on four legs. Some of the dinosaurs also developed very long necks, which made it possible for them to reach heights of 15 metres.

From this viewpoint, it is easy to understand why the giant redwoods finally became—their ancestors having co-existed with the high-browsing dinosaurs for tens of thousands of millennia—what they still are. Even a *brachiosaur* or a *seismosaur* would not be able to reach the foliage of a large redwood tree for thousands of years, after the tree had survived its dangerous childhood years.

A hundred million years ago, there probably were a vast number of diverse redwood species growing on earth. Only two of them have survived till our days. One is the giant redwood (*Sequoia sempervirens*); the other is the sierra or mountain redwood (*Sequoiadendron giganteum*).

The tallest trees growing in the world today are giant redwoods. The tallest specimens have reached the astonishing height of 112 metres. However, the sierra redwoods have probably originally beaten them in height. The largest known *S. giganteum* is now only 83 metres tall, but its height was probably around 120 metres before it lost its crown. In any case, the giants of the sierra probably are the largest trees in the world, when it comes to the volume of wood.

The largest remaining sierra redwood tree, which the indigenous people used to call the 'Father of the Forest' (and which the less civilized Anglo-Americans have, somewhat irritatingly, christened 'General Grant') is 83 metres tall and 10 metres in diameter at the shoulder height. The lowest branch of this giant tree grows at a height of 45 metres, and has a length of 45 metres and a diameter of two metres. In other words, the lowest branch of the 'Father of the Forest' is larger than the largest known elm tree and it is growing higher from the ground than the crown of the largest known elm.



It has been estimated that the weight of this giant tree is about 6,100 tonnes. According to researchers, the sequoiadendrons can become at least 6,000 years old. After they have passed their youthful years, they are highly resistant to even major forest fires: the bark of the old sequoiadendrons can have a thickness of 60 centimetres. There are not so many sequoiadendrons left in nature, and most of them grow widely separated from each other, surrounded by a mass of smaller trees. However, here and there, small groups of sierra redwoods grow quite close to each other.

The giant redwoods do not grow quite as impressive girths as the sequoiadendrons. However, they can sometimes form large, surprisingly dense—considering the size of the trees—and uniform natural stands. According to Hugh Johnson:

> The biggest surprise on seeing them for the first time is not so much the height of the trees, for it is almost impossible to stand back and survey one; it is the way they stand shoulder to shoulder, sometimes leaving scarcely room for a man to squeeze through between two trunks each 20 feet thick.

Because of this quality, it is possible that the giant redwoods could grow a larger storage of organic carbon than any other tree species in the world. The old-growth stands of giant redwoods can contain up to 4,000 tonnes of above-ground biomass per hectare. The average, however, is much less. According to one estimate, it would only be slightly more than 400 cubic metres of trunk wood per hectare, which is, actually, surprisingly little. One explanation is that the giant redwoods and sequoias are ancient species which were rapidly losing in the competition against the more modern trees, even before the coming of man. In nature, the giants are usually surrounded with numerous smaller trees that do not reach quite similar proportions.

Another explanation is that the presently existing redwood forests are, on average, less magnificent than they were in the beginning of the nineteenth century. The best forests that contained the highest volumes of wood were logged first, so the average for the still existing natural stands does not give a very representative picture.

According to the analysis of Susan Pritchard and her co-workers, the average carbon storage in the redwood ecosystems in 1910–1924 was at least 629 tonnes of carbon per hectare, and probably more than this. However, it was estimated that 70 per cent of the total carbon storage was in the coarse litter, humus and soil, and only 30 per cent in the trees. Also, it was estimated that one-third of the biomass of the trees was in the roots. A well-managed sequoia or sequoiadendron monoculture might finally produce a wood storage that is several times larger than this natural average.

Giant redwoods are, somewhat surprisingly, the fastest growing conifers in the temperate regions. A young redwood stand can annually produce 28 cubic metres of timber per hectare. A second-growth redwood forest stand near Fort Bragg, California, produced 1900 cubic metres of wood per hectare in 137 years. The basal area of this 137-year-old stand was an astonishing 250 square metres per hectare—which is almost unbelievable for a relatively young forest.

Like the giant sequoias, the so-called swamp cypresses are also a gift left for us by the dinosaurs. Perhaps the most striking species is the Montezuma cypress (*Taxodium mucronatum*). The largest tree in Mexico, called 'El Gigante' (the giant), belongs to this species. El Gigante is an ancient tree growing in the city of Tule, in the state of Oaxaca. The height of the tree is 41 metres, which is not exceptional. But its diameter is 13 metres (which means a girth of 40 metres). It has been estimated that El Gigante is at least 1,000 years old. Its growth has been monitored since 1580, and it seems that the diameter of the tree is still growing at the steady speed of 12 centimetres in a decade. So nobody knows how big El Gigante will finally become.

The still standing Montezuma cypresses are usually individual trees—ancient forests consisting of Montezuma cypresses are long gone. However, such forests have certainly existed before. One



wonders what might these forests have been like during the height of their reign...

## The Jujube Family (Rhamnaceae)

The ber or the jujube is one of the ancient fruits of India and China. Ber has a phenomenal ability to withstand drought. For this reason it has often been called 'the king of arid land fruits' or 'the desert apple'. The jujube family contains about 50 genera and 600 different species. In the actual jujube genus, there are approximately 50 species, many of which produce edible fruit. Eighteen to 20 of these species are native to India. The most important species are the Indian jujube (*Zizyphus mauritiana*) and the Chinese jujube (*Z. jujuba*).

Indian scientists working in CAZRI (Central Arid Zone Research Institute) have bred improved varieties of *Z. mauritiana*.

Ber trees are usually planted with a density of 100–150 trees per hectare. The average yield of the improved varieties in their prime age of bearing varies from 80 to 200 kilograms per tree per year. In dry areas, the yields are lower, from 50 to 80 kilograms per tree. Ber fruits are, in calorific terms, more nutritious than apples and they are also rich in vitamins C, A and B. The fruit can be eaten fresh, preserved (dried) or made into sherbet.

Ber leaves are excellent fodder and the valuable wood is used in furniture. Because the tree requires regular pruning, it is also a good source of high-quality fuelwood. The tree can withstand extremely hot conditions by shedding its leaves, but it is sensitive to freezing temperatures.

The name *zizyphus* comes from the Arabic word *zizouf* which means 'nut-bearing lotus'. *Zizyphon* is Greek for *jujube* or 'edible plum-like fruit'. *Zizyphwn*, the Latin word, means the same thing. The Hindi name for the tree is *ber*, and in Sanskrit it is known as *badari*.

A grove of *badari* trees at the foot of Himalayas was chosen for the hermitage of the two great saints, Nara and Narayana, the latter being an incarnation of Vishnu. The site, Badrinath, is a sacred pilgrimage centre for the Hindus. The ber tree is a part of folklore in north India, especially in Punjab. It is considered unlucky to plant it within the house, as it is supposed to make the inhabitants quar-

relsome. The *Dukhbhanjani* or 'sorrow-removing tree' of the Golden Temple in Amritsar is revered by the Sikhs. Apparently, the formal cultivation of the ber tree began when a Muslim contractor won an *Inam* or royal award when he presented a hybrid variety of the fruit to Raja Raghoji Bhonsale II of Ahmednagar.

Ber is a small- to medium-sized evergreen tree with thin vine-like, scraggly, zigzag branches. The bark is cracked, thick and dark grey. The branches droop down and have sharp thorns growing in pairs at the base of the leafstalks.

The leaves are small and far between. They are ovate, dark green on the upper surface and covered with soft white hair on the underside. The flowers are like tiny stars growing in pale greenish-yellow clusters. The fruit is roughly egg-shaped, ranging from small red berries to the longer yellow-green cultivated variety. The skin is hard and thin, and each berry has one stony seed.

## The Dipterocarp Family (Dipterocarpaceae)

The dipterocarp family includes two important genera. One is the dipterocarps themselves (*Dipterocarpus* spp). There are only five dipterocarp species, but their very valuable hardwood is the main reason for the destruction of southeast Asian rainforests.

The other important genus is the sal trees (*Shorea* spp), which provide both valuable timber and edible oilseeds. The South Asian sal, growing in dry tropical forests (*Shorea robusta*), can reach a height of 55 metres and attain a diameter of three metres. Other species growing in the southeast Asian rainforests can be 80 metres tall and thicker than the largest *S. robusta* specimens.

*Shorea* is named after Dr Charles W. Shore, an American botanist. *Robusta* means 'stout'. The Telugu name *gugal* and the Marathi name *rala* both mean 'resin'. The Sanskrit word *shala* means 'rampart'.

In South Asian mythology, sal is the tree of Indra, the King of the gods. It is also the symbol of economic and social welfare, victory in battle, success in life and bumper crops in the fields. Sal is a sacred tree for the tribals, who consider it the home of spirits, and build their shrines under its shade. The Bagdis and Bauris of Bengal are married under an arbour made of its branches. In the villages, the sal tree, when it is in full bloom, is worshipped by childless couples for offspring.



Sal is one of the trees revered by Buddhists, for it is associated with the birth and death of Gautama Buddha. It is said that at the time of his birth in 563 BC, his mother, Queen Mahamaya, seized the branch of a great sal tree. Buddha died in a sal grove. In the *Jatakas*, or legends of the previous lives of the Buddha, tree spirits play a great part, and they are worshipped with perfume, flowers and food. They are depicted as dwelling in many trees, but their particular favourites are sal, semul and banyan.

Sal produces one of the most highly esteemed and valued timbers in Asia. The wood is hard and durable and used for bridge construction, railway coaches, boats, furniture and cart wheels. The market price of sal timber in Nepal and India has been around US$ 300 per cubic metre. The bark is used for tanning and the gum for hardening soft wax in shoe polish.

Sal trees also produce large edible seeds, which are borne in substantial quantities. The seed oil is valuable, because after processing, it substitutes for cocoa butter in the manufacture of chocolate. According to S.S. Negi, sal seeds have traditionally also been used as human food by the indigenous forest-dwelling people of India in three different ways. The kernel of the fruit can be boiled, and a salty butter, suitable as a cooking medium, can be extracted from it. The seeds can be ground into a coarse but nutritious flour and made into bread. Or they may be parched, boiled and eaten. Because sal seeds contain 12–18 per cent oil, they have attracted some commercial interest, and have been used in the manufacturing of a vegetable oil for the Indian markets.

According to the research done by Tirath Gupta and Amal Guleria at the Indian Forest Research Institute in Dehra Dun, Indian forests annually produce around 5.6 million tonnes of sal seeds, only a fraction of which is currently collected and utilized. If the whole crop would be utilized in making vegetable oil, the collection of the seeds would annually provide 1.1 million man-years of employment or, in practice, some part-time employment for 90–100 days a year for several million rural families.

There would also be a lot of potential to expand the production of sal seeds in South Asia. The present acreage of sal forests in India is currently only a small, sad fraction of their original size. Indian foresters have preferred tropical pines (*Pinus* spp), eucalypts (*Eucalyptus* spp) and teak (*Tectona grandis*) in their reforestation programmes, in spite of the fact that they do not produce any food for human consumption. Also, in the areas where sal trees still grow, the forests have often been badly degraded: the trees are few and many of them are in poor condition. The largest and healthiest specimens have been cut for timber and only the inferior trees have been left behind. Professor Sagreya estimated, some time ago, that the actual production of the Indian forests was, due to their degradation and widespread neglect, 8–15 times less than what their actual biological potential would be.

In the Terai region of Nepal, sal is still the most common tree. Even though about 500,000 hectares of sal forests have been lost during the last 20 years, about 1.4 million hectares of forest remain in the Terai. Of this, an estimated 44 per cent consists of sal trees.

There is no reason why the growing of sal trees for valuable timber and for seeds should not be encouraged in South Asia. India and the other South Asian countries will anyway need a lot of good-quality, durable hardwood timber for construction purposes during the coming decades. It has been estimated that the annual demand for such timber will soon exceed 20 million cubic metres. Around eight million hectares of sal forest would be sufficient to provide this amount of first-grade timber. As a by-product, they could also produce a large amount of smaller poles and firewood, and a huge amount of edible seeds.

A lot of employment would be created in the rural areas if the production of sal seeds were multiplied and the whole crop collected to manufacture vegetable oil. Also, the food security of the poorer segments of the population would be greatly improved. Should a war or famine occur, people could survive by supplementing their diets with sal seeds. Because of the high fat and protein content, the nutritional value of the seeds is significant.

Sal wood is very durable. In the excavations at Bulandi Bagh near Patna in 1915, scientists found a large wooden palisade that



had surrounded the old town of Pataliputra. The palisade was almost 35 kilometres long and had 64 gates and 570 watch towers. It was possible to date the palisade accurately, because it had been described by the ambassador of the Emperor of Syria at the court of Chandragupta Maurya, the Emperor of the Mauryan empire from 321 to 297 BC. The timber used in the construction was sal wood, and it had been preserved for 2,280 years.

According to an old legend, the temple of Kathamandasp, which has given its name to the city of Kathmandu, was originally constructed from a single, very large sal tree.

A closely related species, damar (*Shorea javanica*) is often an important component of the highly developed agroforestry systems on the island of Sumatra. Damar is an important resin-producing tree that is usually grown together with a number of other fruit and timber trees. According to the agroforestry researcher, Meine van Noordwijk, the agroforestry systems of the Indonesian islands contain up to 215 tonnes of organic carbon per hectare. This is slightly less than the average for mature forests (365 tonnes) but considerably more than the figure for land under annual crops (63 tonnes).

## The Teak Family (Verbenaceae)

Verbenaceae is a large family of trees, climbers, shrubs and herbs. There are, altogether, more than 3,000 species. They include the teak (*Tectona grandis*), one of the most valuable timber trees of Asia. The English often call teak the Indian oak. The words *tectona* and 'teak' come from the Malayalam word *tekka* which first went into the Portuguese language as *Teca*. The word means 'carpenter'. *Grandis* means 'large'. The Sanskrit name of the tree, *shaka*, means—curiously enough—power, strength and vegetable.

According to Hindu mythology, when the world was divided into *Dveepas* or islands surrounded by the Sea of Milk, one of them was named *Shaka* after the teak tree that grew there.

The teak is a very tall, deciduous tree with a grey-brown trunk. The largest specimens can be 50 or even 60 metres tall. The branches are quadrangular and hairy. The large, rough leaves are elliptical in shape, hairless above but covered with dense red hair underneath. They grow in pairs.

The flowers emerge in dense white pyramidical clusters at the ends of branches. The fruit is round, brownish and spongy. The wood of the teak tree is extremely valuable, as it is insect- and termite-proof. It is used in the building of houses, ships, railway carriages, furniture and musical instruments. The tree also yields a tar used as a varnish. From the bark and flowers comes a medicine for bronchitis. The largest and oldest teak tree in Asia, supposed to be more than 600 years old, is in Kerala's Parambikulam Wildlife Sanctuary.

Another important genus belonging to the same family is vitex, which includes, among other species, the so-called meru oak (*Vitex keniensis*). In spite of the name, the meru oak has nothing to do with the actual oaks (*Quercus* spp). However, the European settlers called it so because the wood had a very fine quality, resembling that of the European oaks. Meru oak could become the most important timber tree and carbon storage tree in the East African highlands. It is not a giant, but it can grow up to 30 metres and have a diameter of two metres at shoulder height. It produces large quantities of small edible fruit. It also produces fine timber which commands a high price in the East African market. For example, in Kenya, meru oak timber has often been worth US$ 800 per cubic metre. Most of the wood is exported to Arab countries, but there is also some demand for it in Europe.

The planting of only a couple of teak, meru oak or tendu (*Diospyros* spp) seedlings can increase the economic security of a rural household—or of the whole larger family—in a very significant way.

## The Ginkgo Family (Ginkgoaceae)

Planting trees has a lot to do with time. When we are planting trees, we often think in terms of temporal perspectives exceeding the human life span. Many trees can live hundreds or even thousands of years. An aspen clone might live a million years.

For those who are interested in such perspectives, the planting of ginkgo trees should be an irresistible temptation.

The ginkgo (*Ginkgo biloba*) is probably the world's oldest still living tree species. It seems that the species has survived for at least 200 million years in its present form.



This should be the most important reason to promote the planting of this triassic tree. However, it is not the only reason for favouring it. The tree produces a large number of small, edible fruits that are about three centimetres in diameter. The kernels are also edible and can be roasted like chestnuts or peanuts. The odour of the rotting fruits is not very pleasant, but this is a minor inconvenience.

Ginkgo isn't one of the actual giants of the plant kingdom, but in the category of fruit and nut trees, it is relatively large. Some specimens in south Europe have reached a height of 45 metres, but it is possible that they could become even larger when planted in warmer regions. Ginkgo achieved its maximum spread during a time when the world was considerably warmer than now, and it may be that the specimens growing in southern Europe are still suffering from a somewhat stunted growth.

Because ginkgo belongs, quite literally, to another world, it has outlived all its natural enemies. None of the insects and diseases that used to feast on the leaves of the ginkgo tree are any longer around, and ginkgos that have been planted as ornamentals always remain surprisingly healthy. For the same reason, ginkgos also contain a large number of chemical compounds that are not found in any other tree. Medicines derived from ginkgo leaves are currently among the most popular pharmaceutical products in France and Germany.

## The Brazil Nut Family (Lecythidaceae)

The brazil nut (*Bertholletia excelsa*) is the king of the large nut trees, often reaching 55–60 metres in height and two or three metres in diameter. The fruits are large and heavy wooden capsules, 10–15 centimetres in diameter, weighing up to three kilograms. Each fruit contains 15–30 three-sided, six to seven centimetre-long nuts in two concentric rings. Large trees usually produce between 100 and 500 fruits. Many people consider brazil nut the tastiest of all nuts.

It is not possible to cultivate brazil nuts as large monocultures, because the trees do not bear any fruit without their natural pollinators, the euglossine bees. Still, the typical yield is 5–7 tonnes of edible nuts (kernels) per hectare. Brazil nut trees are excellent up-

per-storey trees for (climax) agroforestry systems. Attempts to introduce the species to southeast Asia and the Caribbean have failed miserably, which has been unfortunate for the people living in these regions, but good for the Amazonian rainforests.

The nuts are very nutritious, containing 14.3 per cent protein, 10.9 per cent carbohydrates and 66.9 per cent fat. The timber is very valuable.

## The Banana Family (Musaceae)

The banana genus, musa, that includes the various banana and plantain species is named after Antonio Musa, physician to Octavius Augustus Caesar (63–14 BC). The most important species are *Musa paradisiaca* and *M. sapientum*. *Paradisiaca* means 'paradise', of which it is supposed to have been the first inhabitant. It is said that this tree flourished in the Garden of Eden and its leaves were the first garments of Adam and Eve. The Sanskrit word *mocha* means 'juicy' and also 'ascetic' or one who has abandoned worldly passions. *Sapientum*, strangely enough, means 'wise' or 'sage'. The Hindi word *kela* means 'shaking', 'trembling'. Another Hindi name for bananas, *kadali*, means 'flag' or 'banner'.

The botanist Rumphuis writes that the banana came from East India, growing first on either side of the Ganga River, and from there it went to Persia, Syria, Arabia and Egypt. Buddhist sculptures show banana leaves, and a drink called *Mochapana* is mentioned in the Buddhist book of monastic rules.

Although usually called a tree, the banana is really an outsize, broad-leaved, perennial, herbaceous plant. It grows quickly, giving fruit in a year. What is called the trunk is really the pseudostem, the real one being underground. The deep green leaves are enormous, but so soft that they are torn easily by strong winds or storms. Each leaf emerges tightly rolled round its own midrib and then slowly opens out. The leaves that emerge later are shorter, the very last one being very short and hanging protectively over the flowerbud.

Bananas contain iron, minerals, phosphorus and vitamins. It is one of the most important energy-giving foods, and is usually the first solid food given to a baby, as it is easy to digest. Unripe bananas are used as vegetables. The leaves are used as plates. The wild banana plant is used to border crop fields, as it keeps away termites.



Bananas have a lot of nutritive importance, especially for the poorer families living in the humid and sub-humid tropics. The estimated world production of bananas in 1998 was 80 million tonnes, but this is most probably a gross underestimate. The International Development Research Centre (IDRC) of Canada has estimated that the average annual per capita consumption of bananas and plantains in sub-Saharan Africa might be about 250 kilograms. If this is true, the homestead production of bananas in sub-Saharan Africa alone would be about three times more than the official figure for world production. This sounds plausible, because people in Africa do eat very large quantities of bananas, and the number of banana bushes grown on the homesteads has been increasing rapidly during the last several decades, probably much quicker than the human population. In humid Nigeria, bananas and plantains grown under larger trees often produce 60–70 tonnes of fruit per hectare per year. According to Wilhelm Lötschert and Gerhard Beese, annual yields of bananas and plantains can rise up to 100–130 tonnes per hectare in ideal conditions.

Food bananas are much more nutritious than many people realize. Their calorific value is, on average, 490 kJ/100g, which is more than one-third of the calorific content of rice. They also contain about one per cent protein, which is not a very high value, but does have some significance in areas where food bananas are consumed in large quantities. Everybody agrees that bananas are important for people's nutrition and for food security, but the actual extent of their role in the world's food production hasn't really been acknowledged.

There are altogether about 50 species in the musa genus.

One of their more distant wild relatives also deserves a special mention, here. Wild banana or ensete (*Ensete ventricosum*) is a plant growing in the wet upland valleys of Africa. Ensete is larger than the bananas: the stem can be 12 metres high and the large leaves add a few more metres to the height of the plant. It is also more resistant to drought than the bananas. The fruit is not edible, but several other parts of the plant are. The edible parts include the stems and

the corms. The edible parts can be boiled like potatoes when they are young, but the older and tougher ones need to be pulped and fermented in pits for a few months. After that, they can be utilized in the making of more than 20 different local dishes, including cakes, yoghurts and cereal foods. The plant also produces a very valuable fibre, that can be used in the making of clothes.

Ensete was probably domesticated between 5,000 and 10,000 years ago in Ethiopia, and in the seventeenth century, it was still cultivated widely in different parts of the country. A Portuguese priest who travelled at that time through Ethiopia, wrote that ensete was 'the sustenance of most of the people'. Another Portuguese traveller said that

> ...when cooked it resembles the flesh of our turnip so that they have come to call this plant the tree of the poor even though wealthy people avail themselves of it as a delicacy, it is also called a tree against hunger since anyone who has even one of these trees is not in fear of hunger.

It is interesting that ensete was considered as an insurance against famine, especially in those areas of Ethiopia that are regularly hit by severe periods of drought. Later, ensete was replaced by other crops in the northern parts of Ethiopia. The plant is now only used as food in the south of the country, where it supports some of the densest human populations in rural Africa. There have recently been efforts to re-introduce ensete back to north Ethiopia as well.

The archaeologist, Steven Brandt, of the University of Florida, who has studied how people utilized ensete in the past, says that the range of wild ensete covers a major part of West, East and southern Africa. It might, therefore, be a good idea to experiment with growing this dramatic plant as a food crop both elsewhere in humid and sub-humid Africa, as well as in other suitable geographic regions in the South.

According to a South Asian legend, the banana fertilizes itself without cross pollination. So it is regarded as an incarnation of the goddess Parvati. In several parts of India, marriage podiums have banana stalks at the corners. In the Western Ghats, the banana tree is believed to be the Goddess Nanda Devi. Her images are carved out of the stalk and, in the month of Kartika, floated down the



river. In the Mahabharata, Kadalivana, or the banana garden on the banks of Kuberapushkarni, is the home of the monkey god, Hanuman.

The banana plant is considered sacred to the nine forms of the Hindu goddess Kali. In Bengal, marriages are performed under it and it is worshipped in the month of Sravan (July-August). A saying in Bengali goes:

*Kala lagiye na keto pat*
*Tatei kapad tatei bhat*

Do not destroy the leaves of a planted banana.
You will get both your food and cloth.

Since the plant is cut after the fruit is harvested, it has become a folk simile of the bad man destroyed by the fruit of his own deeds.

### The Cactus Family (Cactaceae)

The cacti are another interesting but seriously neglected family of plants, native to South and Central America, Mexico and the southern parts of the USA. Cacti are dryland plants that have developed some very clever evolutionary mechanisms against drought. They keep their stomata, or air channels, closed during the daytime and only take in carbon dioxide during the nights. This reduces their need for water, and makes it possible for the cacti to produce huge amounts of calories compared to the amount of water consumed by them. The king of the family is the huge saguaro cactus (*Cereus giganteus*), that can live for hundreds of years and weigh 15 tonnes. The fruits of the saguaro are edible.

Professor Yozef Mizrahi has cultivated some cacti on an experimental basis in the desert of Negev in Israel. He has concentrated especially on two species: the apple cactus (*C. peruvianos*) and the fig cactus (*Opuntia ficus indica*).

With only 400 millimeters of water (including rainfall and irrigation water) and with some fertilizer added into the irrigation water, the cactus plantations have yielded 40 tonnes of fruit and 400 tonnes of edible cactus flesh per hectare per year. Even though the nutritional value of the fruits and cactus flesh is very low (around 100

kJ/100 g) it is obvious that the cactus trees could play a role in dryland agriculture.

At the moment, the only country in which cactus flesh is consumed on a large scale as food for humans is Mexico, where cacti have major cultural and religious importance, and where the most important food-producing cacti are sacred trees for many indigenous peoples. Cactus flesh is also eaten by the mainstream population in Mexico, but it is hard to say whether it will become popular in other countries as well.

One desirable option for all the dryland areas, however, might be the use of edible cacti as living fences. Because of their sharp spines, cacti can make a formidable, impenetrable living fence, and cattle cannot eat the cacti unless people remove the spines with a machete or another kind of tool. Unlike an ordinary fence, which is much more expensive to establish, a cactus fence can produce edible fruit. And, in time of a drought, the people can remove the spines from the cacti and use them as fodder for their cattle—or food for themselves.

However, a little note of caution should be kept in mind here.

If the local people really start to consider cactus flesh as food, the introduction of edible cacti into another geographic area probably won't cause any major problems. However, if this does not happen, cacti can become very harmful weeds.

Some time ago, scientists bred spineless opuntia varieties and introduced them to Australia as fodder crops. However, they had not continued the breeding process long enough. The spine-growing characteristic did still exist in some of the cacti, although in a recessive, and not in a visible form. When the opuntias started to breed in the wild, some of the offspring had spines and some had not. Because cattle could eat only the spineless ones, the spiny varieties became more and more numerous, and they started to gain ground from all the other plant species that were eaten by the cattle. Finally, the spiny opuntia cacti stands covered tens of millions of hectares of pasture land. The problem was finally solved by the introduction of pests against which the opuntias didn't have any resistance. Besides the opuntia and cereus genuses, numerous other cacti are also edible.



## The Yam Family (Dioscoreaceae)

The yam and its relatives are woody climbers that produce edible tubers. Some species produce tubers under the ground (subterranean tubers) and some above the ground (aerial tubers). Some species can produce both. Yam is usually cultivated by letting the plants climb up tall trees. In the Caribbean, the yields vary between 10 and 30 tonnes per hectare, and in East Africa, between 12 and 25 tonnes. The tubers can be left in the ground for a long time and eaten when they are needed.

## The Pawpaw Family (Caricaceae)

The pawpaw genus (*Carica* spp) includes 30 smallish and short-lived species of trees that are natives of the Americas. Most of the species produce edible fruit. The most important one is the pawpaw (*Carica papaya*), which was domesticated by the indigenous peoples of Mexico several thousands of years ago. The fruit weight can exceed seven kilograms, and the largest recorded annual yields have been more than 100 tonnes per hectare. The nutritional value of the fruit is about half the calorific and protein content of the potato.

## The Bamboo Subfamily (Bambusae)

The approximately 1,000 species of bamboos belonging to the bamboo subfamily of the grasses are among the most useful plants of the world. Bamboos are not real trees, but giant grasses growing to tree-like dimensions. The king of the family, giant bamboo (*Dendrocalamus giganteus*) can grow 40 metres tall and more than 30 centimetres in diameter.

Bamboos are often called the poor man's timber, because they make a strong but cheap and light construction material. For many purposes, bamboos are stronger than steel, which is due to the extraordinary design of the bamboo culms (stalks). The stalks are hollow and they contain nodes (joints) that add to their strength. Moreover, there are numerous columns of living tissue scattered inside the stalk walls. This makes bamboo stronger than ordinary wood, which only has a thin layer of living tissue under the bark.

One of the great wonders of bamboo architecture is the Min River bridge in Sichuan, China. The great, more than 1,000-year-old bridge hangs from 20-centimetre-thick bamboo cables.

There has recently been a lot of hi-tech euphoria around a new class of materials that are called composites or two-phase materials. Scientists have found out that it is possible to produce extremely strong materials for aerospace industries and numerous other purposes by arranging different man-made or natural fibres in parallel bundles, separated by other kinds of materials. Engineers have spoken about a revolution in material science. However, in practice they are only imitating the structure of the bamboo stalks.

Because bamboo is already, in itself, a natural composite material, it could make a superstrong but superlight 'double composite' when combined with suitable new materials. American scientists have even proposed that bamboo could be used—and this is not a joke—in the construction of rockets and space ships. The first rocket weapons in the world, which were used by the Indians against Alexander's Graeco-Persian army 2,400 years ago, were also made of bamboo stalks.

In our time, Indian scientists are developing numerous new ways to utilize the unique structure of the bamboos. They have replaced steel reinforcements in concrete and steel bolts with bamboo, and made windmill blades and boat hulls from it. In the future, bamboo or composite materials based on it could perhaps also be used in cars and in other vehicles instead of steel. This would enable us to manufacture cars that are much lighter without lessening the strength of their hulls. The oil or gasoline consumption of such lightweight cars would be only a fraction of what our present models are burning. Also, the manufacture of steel consumes a lot of energy and produces high emissions of carbon dioxide. Bamboo grows by itself: it does not have to be manufactured in a factory. Replacing steel with bamboo could thus play an important role in the efforts to prevent a greenhouse catastrophe.

Another benefit of the bamboos is their rapid growth. One species (*Phyllostachus bambusoides*) holds the world record of growing almost one metre and twenty centimetres in 24 hours. Unfortunately, such speeds can only by maintained for short periods of



time. Still, even with the larger bamboos, the crop grows to its full size in three or four years. This makes it possible to produce very large amounts of strong timber on one hectare. Many species also produce edible shoots.

The most amazing peculiarity of the bamboos is their flowering habit. Most species flower very seldom—once in 30, 60 or even 120 years. But when a certain species decides it is time to flower, all the individual plants that belong to the same species start to produce flowers, even if they are growing on different continents. This biological clock of the bamboos is one of the true wonders of nature.

### The Wood Apple Family (Rutaceae)

The bael (*Aegle marmelos*) is an important fruit tree in South Asia with major cultural significance. A mature, well-cared for tree will annually produce between 300 and 500 large round fruits that are nutritious and have a number of uses. The fruit has a hard, wooden shell. The bael fruit pulp can be made into sherbet or syrup. It is used as a specific cure for dysentery, mixed with lime to make cement, and used in paints for a glossy finish.

The wood is used for houses, carts and tool handles. The unripe rind makes a yellow dye used in calico printing. The leaves make poultices for the eyes and the roots are used for the treatment of fever. Between 100 and 150 trees are usually grown on each hectare.

*Aegle* is the Latin name for one of the Hesperides, the three sisters who, helped by a dragon, guarded the golden apples of the goddess Hera. *Marmelos* comes from the Portuguese word *marmelosde* meaning 'marbled'. The Sanskrit word *shriphala* means 'sacred fruit'. In Hindi, the tree is known as *bael*, *bilva* or *sriphal*.

The bael is considered sacred to Shiva, and as an offering of its leaves is a compulsory ritual, it is usually planted near a Shiva temple. *Bilvádandin*, 'he who has a staff of bilva wood', is another name for Shiva.

On the seventh day of Dashera, the night of the Great Worship, the Rajput kings would perform the Invitation to the Bael Tree, considered the most sacred of Dashera rites. A bael fruit was picked fresh from the tree and offered to the fierce goddess Chamunda in order to invoke her protection.

In Bengal, the goddess Durga is aroused from her sleep during Durga Puja by touching a twig from a bael tree growing in a north-easterly direction. The goddess is invoked to awake and take up her abode in it.

In Bihari folklore, common proverbs centre round the tree. *Phir mundlo bel tal* ('the bald head will not venture under the bael tree again'). The bael fruit is said to be attracted to shaven heads and will never resist a chance to fall on one. The English equivalent would be: 'Once bitten twice shy.'

A proverb illustrating indifference says: *Bel pakal, kawa ke baap la ka*, 'what difference does it make to the crow if the bael fruit is ripe?' The crow, which pecks at all ripe fruit, cannot penetrate the hard shell of the bael, so it is immaterial to the bird when the fruit ripens.

It is said that the presence of the bael and a ber tree together indicates an underground spring. According to Tantric folklore, Lakshmi came down to earth in the form of a cow. From the dung of this sacred animal arose the bilva tree. Lakshmi, depicted in the Bhuvaneshvari Tantra, holds a bilva fruit in her lower left hand, an image that signifies her as the deliverer of the fruits of one's actions.

People go round the bael tree before starting something, as the tree is supposed to grant success in new ventures. Vasyman, the king of the Videhas, is said to have regained his lost kingdom by going round the bael tree at the temple of Tiruvidaimarudur.

### The Pomegranate Family (Punicaceae)

The most important member of this family is without doubt the pomegranate (*Punica granatum*) itself. Pomegranate trees can tolerate salinity and saline irrigation water and do well even in shallow soils. They can also tolerate severe drought. The fruit is rich in sugar and 5–12 centimetres in diameter. The best plantations can annually produce up to 50,000 fruit per hectare.

Pliny called the pomegranate 'the Apple of Carthage', *Malum punicum*. The term means 'grain apple', a reference to the grain-like seeds within. *Pomegranate* comes from the French word *pome garnete* or 'seeded apple'.



In Sanskrit there is an adage, *dadima mani dansh*, 'to bite the pomegranate tree'. This means 'a hard and unwelcome task'.

The pomegranate is a symbol of fertility and prosperity. The pomegranate motif is found in temple carvings. Prophet Mohammad is said to have advised his followers to eat pomegranates as a way to purge the spirit of envy.

The Parsis use its twigs to make their sacred broom. When a Parsi child is invested with the sacred thread, pomegranate seeds are thrown over him to scare away evil spirits. Its juice is squeezed into the mouth of the dying.

The pomegranate is a small, rounded, bushy tree. It has stiff, slender, spiny branches. The trunk is erect and red-brown. (It later turns grey.) The tree has both evergreen and deciduous varieties.

The leaves are borne in clusters. They are small, narrow, lance-shaped, glossy and leathery. When young, they are brownish green. This colour darkens as they age. The vermillion-tinged orange flowers are broad. They have crumpled petals and a red, fleshy calyx which remains on the fruit. The flowers grow at the end of the branches.

The fruit is a deep red berry. Its outer skin is hard and thick. Inside it has a great number of seeds, each in a small cell surrounded by a carmine pink flesh. Once the fruit is ripe, it splits open or 'laughs'.

The fruit is eaten. Its seeds are dried and made into a condiment for curries. Every part of the tree has medicinal properties. The wood is used for agricultural implements.

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## About the Authors

**MANEKA GANDHI** has been the minister of culture and animal husbandry, minister of environment and minister for empowerment and social justice in the Government of India. As the minister for environment she negotiated the Montreal Protocol for India, a treaty that eliminated the ozone-depleting CFC emissions and simultaneously cut the world's greenhouse gas emissions by 25 per cent. Mrs Gandhi is also the most well-known modern animal rights activist of India, and the founder-trustee of People for Animals, India's largest animal welfare organization. She has written several books about varying subjects and used to make a popular animal rights programme 'Heads & Tails' for Doodarshan both in Hindi and English.

**RISTO ISOMÄKI** is a writer, a former chairman of Friends of the Earth Finland and the secretary of the Coalition for Environment and Development (CED). He is also a Founding Member of the Democracy Forum Vasudhaiva Kutumbakam. He has acted as a board member or as a coordinator of a number of international citizens' campaigns and networks, including the International Nestle Boycott Committee and the Justice for the Amazonian People campaign. Mr Isomäki has also written the scripts for or co-produced a number of award-winning documentaries and drama-documentaries.